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OIL SEED PRODUCTION IN THE TROPICS AND SUB-TROPICS

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This study deals with each of the seven annual oil seed crops, as to their respective plant characteristics; ecological adaptation; uses; cultural practices for higher levels of productivity; world production centers; and world trade in the oil seeds, their extracted oils, and the cake or meal derived from extraction of the oil.

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STAFF PAPER

"OIL SEED PRODUCTION IN THE TROPICS AND SUBTROPICS"

Characteristics of Seven Annual Oil Seed Crops,
For Use as a Guide to Choosing One or More for
Commercial Production.

Office of Agriculture
Bureau for Technical Assistance
U.S. AGENCY FOR INTERNATIONAL DEVELOPMENT

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Comparison of Annual Oil Seed Crops

This study is oriented toward the problem of selecting one or more of the oil seed crops by an individual country, for inclusion in its program of development. It is not intended to serve as a comprehensive guide to the cultivator, on efficient production of a specific crop.

When any country has made a decision on which oil seed crop is to be given special attention, then a special publication or guide for the cultivator and research worker may be issued. Such a publication would deal with cultural practices, control of diseases and insect pests, harvesting, etc. as an aid in searching out and overcoming production problems. That publication should be directed to the conditions in a specific country or region.

The attached publication is intended to provide basic information on each of the 7 crops that has some potential for inclusion in cropping systems. This basic information should be useful for evaluation of each crop's suitability for meeting the economic needs of individual countries.

Oil Seeds Production in the Tropics and Subtropics

Introduction

This study is intended to survey the importance of annual (vegetable) oilseed crops in developing countries and to provide certain basic information as to the characteristics and utility of the more important types. The species considered include groundnuts, sesame, sunflower, safflower, cottonseed, soybeans, and castorbeans. The first six are edible and have multiple uses; but castorbeans are toxic and inedible, and are grown for industrial uses only. This study does not deal with oil producing tree crops; oil palm, olive, tung, and coconut.

Annual oil seed crops are attractive enterprises for farming systems in tropical and subtropical regions, and the individual countries may wish to select only those species for attention that seem to be most profitable. This study treats each of the crops individually, as well as providing comparisons between them.

The choice of an oil seed crop, for any specific region is determined by two major factors; (1) the yields that may be expected under local conditions of climate and soil when cultural practices make full use of modern technology, and (2) the prices that the various crops can command in the open markets of the country and in world trade. The net market value of the harvested crop to the producer when all production costs have been covered, is doubtless a major criterion for selecting a preferred oil seed crop. However, the net value of alterna-

tive crops must also be considered in deciding whether to include a particular oil seed crop in the local farming system.

This study deals with each of the seven annual oil seed crops, as to their respective plant characteristics; ecological adaptation; uses; cultural practices for higher levels of productivity; world production centers; and world trade in the oil seeds, their extracted oils, and the cake or meal derived from extraction of the oil.

The merits of annual oil seed crops for inclusion in farm production systems may be summarized as follows:

Attractiveness of Annual Oil Seed Crops in Developing Countries

(Annual Crops; Groundnuts, sesame, safflower, sunflower, cottonseed, soybeans, castorbeans)

1. Six of the 7 major annual oil seed crops are edible for man and livestock; as whole seed, oil, and cake or meal after oil extraction. Castorbean is toxic and non-edible.

   a. The oils of 6 crops are suitable for cooking, as well as for processing into margarine; and for a variety of industrial uses.

   b. The cake or meal produced from dehulled seed is high in total protein, and is a useful protein food in human diets and for livestock feed.

   c. The cake or meal from unhulled seed (cottonseed, sunflower, safflower) is a valuable high protein feedstuff for livestock.

   d. Groundnuts and sesame are well suited for direct use as food in the home. Sunflower and safflower seeds must have hulls removed; and the hulled seed is suitable for home use as protein foods. Mature soybeans should be fermented or sprouted to make them digestible by man; but soya cake and meal produced by high temperature oil extraction, is a valuable high protein foodstuff for man and feed for livestock. Cottonseed meal produced by oil extraction from naked kernels, may become a high protein food; and the cake produced by oil extraction of unhulled seed is a valuable protein supplement for ruminant livestock.

2. All of the 7 oilseed annual crops are adapted to the tropics and subtropics, particularly the moderately humid to subhumid regions. The possible exception is the soybean, which doubtless will require breeding to develop varieties that are not sensitive to length of day; the traditional world production centers for soybeans are in the temperate zones.

3. The mature seeds are easily stored and processed, and can be handled as staple commodities in much the same manner as grains.

4. There is an extensive international trade in these oil seeds, and in the oils produced from the seeds. These are high value commodities, with multiple uses as foodstuffs, feeds, and in many aspects of industry.

5. They may serve as cash crops for the individual producer, as earners of foreign exchange for the nation, and 6 of the crops may serve as important protein foodstuffs for urban people, and as protein supplements for livestock. They rank second only to food grain legumes as sources of protein to supplement the universally inadequate supplies of animal proteins (meat, milk, eggs, fish).

6. Annual oil seed crops are readily included in cropping systems, and may be used to increase total farm income, to more fully utilize local labor, to provide more versatility in production and to reduce the hazards of damage and loss by reason of greater diversity in crops.

Oilseeds as protein foods. There is a grave shortage of protein foods in the less developed regions of the world; and the possibility of increasing production of animal proteins (meats, milk, eggs, fish) to not only correct present deficiencies but also to keep pace with growing populations, is highly unlikely. As an alternative, high protein foods of plant origin must play an important role in providing balanced diets. The edible oil seed crops should play an increasingly important role in meeting dietary protein needs. They are high in total protein; and when the high-value oil is extracted, the resultant cake or meal has even greater value as a protein food than the original seed.

Protein malnutrition in man is much more serious and devastating than mere shortage of food energy: The human body can adjust to shortages of calories by reducing physical activity for extended periods, and then recovering when foods become available. Protein needs are constant, and deprivation may produce damaging effects that are irreversible.

The quality of proteins from oil seeds when used to meet dietary needs is shown in table 1.

Table 1. Average Nutritional Value for Man, of Proteins from Oil Seed Crops*

Crop	Average Protein Content (whole seed)	Nutritional Value of Protein (in relation to egg protein)	Principal Limiting Amino Acids (1)
A. Groundnuts	25.6%	69%	Methionine and cystine
B. Sesame	18.1%	63%	Lysine
C. Sunflower	12.6%	93%	Lysine
D. Safflower	12.6%	71%	Methionine and cystine
E. Cottonseed	20.2%	76%	Methionine and cystine
F. Soybeans	38.0%	62%	Methionine and cystine

(Note: Castorbean is toxic and inedible, and is not included in this table)

(1) All proteins of plant origin are more or less unbalanced in the necessary ratios of essential amino acids required for human diets, in contrast to animal proteins which are well balanced.

*Derived from FAO publication: "Amino Acid Content of Foods, and Biological Data on Proteins. 1970.

A. Groundnuts (*Arachis hypogaea*)

Introduction

Groundnuts belong to the legume family, and the plant typically satisfies its need for nitrogen through specific root nodule bacteria. When effectively innoculated with such bacteria, the plant is largely independent of soil nigrogen supplies and of nitrogen fertilizers. This trait is important in understanding the successful growth of the crop under a wide variety of soil conditions.

Although the groundnut is probably a native of tropical South America, it is now grown widely in warm climates around the world. Commercial production of groundnuts for national and world trade began in the latter part of the 19th Century, but the crop began to be used locally for food as soon as the plant was introduced by ships traveling from South America to other parts of the world. The use of whole nuts, groundnut oil, and groundnut cake and meal for food and other purposes on a global basis has made it the major annual edible oil seed crop for home use not dependent on industrialization. Both cottonseed and soybeans have achieved higher production than groundnuts in recent historic times but both of these are dependent on industrial processing. Groundnuts continue to have great economic importance around the world.

Uses:

Groundnuts are widely used for food in the home; they are marketed in the shell as cash crops; and they are processed for oil and meal, which enter regional and world trade channels.

Groundnuts are rich in protein, and constitute an important protein food to supplement animal proteins in the human diet. See Table 1.

As is true for all proteins of plant origin, groundnuts are not completely balanced in essential amino acids content, but they are an important foodstuff to supplement diets composed largely of cereal grains, root crops and other energy foods.

Groundnut cake or meal is higher in protein than the whole nut (see Table 4), and is an important protein food. Groundnut cake or meal also is satisfactory protein supplement for poultry and pig feeding, as well as for ruminant livestock. The average chemical composition of whole groundnuts, and of the cake or meal is given in Table 4.

Groundnut oil is edible; it is used for cooking, for margarine, in dressings and in various food products, and for specific industrial purposes.

World Production

Production of groundnuts is summarized in Table 2. The crop is widely grown in warm regions of the world, particularly Asia and Africa. Average yields of nuts for specific countries are shown in Table 3, which also gives comparative data for other oil seed crops.

Groundnuts are grown in many countries as a commodity entering into world trade, as unshelled nuts, groundnut oil, and cake or meal. The actual total production is probably 25 to50% greater than world statistics indicate, because of the extensive use of groundnuts for food by the families in rural areas. There is a great range between countries in yields per hectare, ranging from an average of 250 Kg. to 2350 Kg. per hectare. Some of these great differences are due to soil and climatic limitations, but a larger part is probably the result of low level technology applied to the crop. World trade in all of the oil seed crops

and their products is quite impressive, and is reported in some detail in Table 5. West European nations constitute the most important market (Table 5.), and this market may be examined in the light of the major producing regions shown in Table 2.

World Trade

Europe is the major importing market for unprocessed groundnuts, for groundnut oil, and for groundnut cake and meal. See Table 5. Europe imported groundnuts and products with a total value of $650 million; greater than any of the other edible oil seeds in this group of six crops, with the exception of soybeans. Groundnuts exceeded all of the oil seed imports by Europe when North America was excluded as a source of oilseeds.

The major importing countries for unprocessed groundnuts are as follows:

For Europe - France, Portugal, Italy, West Germany and United Kingdom

For North America - Canada

For South America - Venezuela

For Asia - Japan, Hong Kong, Malaysia, Singapore

For Africa - Mozambique, Algeria

Trade in Groundnut Oil, 1969 (Table 5. Part II)

European imports account for nearly 85% of the total world imports of groundnut oil. The major importing countries were France, United Kingdom and West Germany. Venezuela was the principal importer in South America; and Hong Kong and Singapore dominated the Asian market. Canada was the only significant importer in North and Central America.

Trade in Groundnut Cake and Meal (Table 5, Part III) 1969

The European market imported about 90% of the groundnut cake and meal that entered world trade in 1969. The United Kingdom, France and West Germany were the major importers in Europe. Japan dominated the Asian import market; and Réunion and Zambia were the principal importers in Africa.

Description:

This crop is known as "peanuts" in North America, and has various common names in other regions. It is a member of the legume family, but is unique in bearing the pod below the soil surface. It is a low growing annual with a central upright stem, with numerous branches varying from prostrate to nearly erect in different varieties. There are two main types of varieties, the "bunch" and "runner" types, which are descriptive of the placement of the pods in the soil with respect to the central stem. The pods containing the nuts, tend to be clustered about the base of the stem in the bunch type; and the runner types have nuts scattered along their prostrate branches from base to tip.

The flowers are borne in leaf axils, above or below ground, singly or in clusters of three. After flower pollination takes place, the flower stem elongates and pushes the developing ovary into the soil where the pod develops. The moisture content of the surface soil around the pod, and its supply of soluble calcium and phosphorus have a pronounced influence on the development of the pods and its nuts. The seed is a linear embryo, covered with a thin, colored seed coat; and there may be

one, two or several seeds per pod, depending on the variety. Since the seed is borne underground, the crop must be harvested by digging, and careful drying is necessary to avoid development of harmful molds.

Varieties:

Named varieties of groundnuts have been developed in various countries where the crop is grown, and in addition there are local types termed "landraces," each of which has specific characteristics and ecological adaptation. The named varieties have been bred or selected for suitability to a particular region and may or may not have wide adaptation that would make them superior in other regions. Their suitability to a different region can be readily established by field trials in the district where the crop is to be grown, in which all strains or varieties are given equally favorable conditions and treatments.

"Landraces" collected from many different regions and parts of a country offer considerable opportunity for finding inherited resistance to diseases and to insect pests, for adaptation to specific ecological conditions of climate and soil, and for agronomic traits such as length of growing season, height of plant, non-shattering of grain, and grain quality. The so-called "World Collections"* of each crop species should be used whenever available, to supplement the collections of types and strains that may be made in a specific region.

Ecological Adaptation

Groundnuts prefer moderate rainfall during the growing season, an abundance of sunshine, and relatively high temperatures. The growing period for most varieties ranges from 120 to 140 days. Planting dates in the tropics and sub-tropics should be adjusted to utilize the most favorable period as to the occurrence of rainfall. The two most critical growth periods from the standpoint of limited rainfall are the period of germination and plant establishment, and the period from flowering until harvest. Good drying weather is particularly desirable at time of harvest, to facilitate rapid drying after the nuts are dug, so as to prevent or minimize any development of molds. Commercial production of groundnuts probably should be limited to regions that are assured of good drying weather at harvest time.

The best yields of market groundnuts are produced on well drained sandy loam soils. The soils should not be strongly acid in nature; and moderate soil fertility is preferable. The supply of available calcium and phosphate in the surface layer of soil should be fairly ample to foster growth of the pods and nuts, after the flower stem pushes the developing ovary in the soil. The surface soil should not be crusted at blooming time so as to foster easy penetration of the young pod; and a moderate amount of moisture is required in the soil layer penetrated by the developing pods after blooming to insure good crop yields.

Cultural Practices

Groundnuts tend to deplete the soil in fertility, and are most productive when grown in rotation with other crops, all of which should receive some fertilizer. This is particularly true when the vines are consumed by livestock, and not returned to the soil. In the United States, groundnuts grown in a three-year rotation yielded three times as much over a period of years, than groundnuts grown on the same land every year. Where there is danger of soil blowing and wind erosion at any season of the year, alternating strips of groundnuts and maize (or millet, or sorghum) has been effective.

Although the immediate responses of groundnuts to applications of fertilizer are often disappointing, the crop does benefit from fertilizers applied to previous crops. The most important fertilizer elements are phosphate and potash, although nitrogen is needed on most sandy soils. In addition, lime may be needed on those soils not naturally well supplied with calcium. The ratio between the three fertilizer elements, and the amounts to use must be determined by field trials in each region. However, all fertilizers for groundnuts should be evenly spread over the field and worked into the topsoil as much as possible. Failure to insure adequate fertility will result in steadily declining yields, irrespective of other cultural practices.

The seed bed should be prepared in advance of the desired planting date, particularly in drier climates, so that plantings can be made promptly when rains occur. Unshelled pods may be planted, but breaking the pod into pieces with one nut per piece is recommended.

Shelled nuts are preferred for planting in some regions. Seed treatment with a fungicides is helpful in getting good stands of plants, particularly if germination is likely to be slow, or if the soil becomes overly wet. Inoculation of the seed nuts with an appropriate strain of nodule forming bacteria, is important on fields where the crop has not been grown in recent years.

The seed should be planted in a mellow seed bed, preferably in rows about 25 to 30 cm. apart, with seeds spaced about 15 to 20 cm. apart in the row. The density of seeding should be reduced where rainfall is likely to be below optimum during the growing season. Weeds may very seriously reduce yields by crowding, competing with the crop for soil moisture and fertility, and overshading the low-growing crop. Weed control continues to be important until the crop is mature. Weeds should be controlled by means that will not damage the groundnut root system nor the developing underground pods of the crop.

The crop is ready for harvest as soon as the kernels are full grown and the skin on the kernels begins to color and show darkened veins. Premature harvest results in shrunken nuts. In harvesting, the vines are lifted, shaken to remove the soil, and left in small piles or windrowsto dry. Turning the vines at one or two day intervals, to expose the shells to the sun will hasten drying and reduce hazards of molds. Removal of pods from the vine should not be done until the stems connecting pods to the mother plant are brittle. This may take two or more weeks depending on occurrence of rains and air humidity.

Rapid and thorough drying is highly essential for marketable groundnuts. The crop is usually sold as unshelled nuts, since all subsequent market processing can be easily mechanized. Local village processing plants may be effective for shelling, roasting, and other preparations for home use of the nuts as food. On-farm storage should be based on groundnuts in the shell, protected from moisture and from rats and mice. Insect damage and molds are more easily controlled by such storage, than for most grain crops.

Table 2 Production of Annual Oil Seed Crop

Region	Area 1000 Ha.	Production 1000 M.T.	Yield 100 Kg/Ha	Principal Producing Countries
A. Groundnuts 1970				
Europe	12	19	15.8	Spain, Greece
So. America	903	1,184	13.1	Brazil
Asia	9,582	8,187	8.5	India, Burma, Indonesia, Thailand
Africa	5,845	4,760	8.1	Nigeria, Senegal, Sudan, Uganda Zaire, Cameroon
No. & Central America	751	1,547	20.6	USA, Mexico, Dominica
(Mainland China & USSR are excluded)				
B. Sesame Seed 1970				
Europe	16	6	3.6	Greece, Bulgaria
So. America	231	136	5.9	Venezuela, Colombia
Asia	3,266	722	2.2	India, Burma, Pakistan, Turkey, Thailand
Africa	981	367	3.7	Sudan, Ethiopia, Uganda, U.A.R.
No. & Central America	325	270	8.3	Mexico, Nicaragua
(Mainland China & USSR excluded)				
C. Sunflower Seed 1970				
Europe	1,166	1,566	13.4	Rumania, Bulgaria, Spain
So. America	1,461	1,234	8.4	Argentina
Asia	361	391	10.8	Turkey
Africa	297	178	6.0	So. Africa, Ethiopia
No. America	119	109	9.2	USA, Canada
(Mainland China and USSR excluded)				
D. Safflower (1)				
Europe	N.A.	10	N.A.	Spain
So. America	N.A.	12	N.A.	Paraguay
Asia	N.A.	226	N.A.	India, Turkey
Africa	N.A.	Negligible	N.A.	Egypt, Morocco
No. America	N.A.	403	N.A.*	USA, Mexico, Canada
	N.A.	11	N.A.	Australia
(1) All data are unofficial			*Experimental Fields=28 hundred ka/ha	
E. Cottonseed 1970				
Europe	332	311	9.4	Greece
So. America	3,787	2,026	5.3	Brazil, Colombia, Peru
Asia	11,361	4,837	4.3	India, Pakistan, Turkey, Syria, Iran
Africa	4,632	2,432	5.3	Uganda, UAR, Sudan, Tanzania, Nigeria
No. & Central America	5,282	4,818	9.1	USA, Mexico

Table 2 (con't)

Region	Area	Production	Yield	Principal Producing Countries
	1000 Ha.	1000 M.T.	100 Kg/Ha	
F. Soybeans 1970				
Europe	95	87	9.2	Rumania
So. America	1,288	1,637	12.7	Brazil
Asia	1,616	1,177	7.3	Indonesia, So. Korea
Africa	43	29	6.7	None significant
No. & Central America	17,463	31,493	18.0	USA
(Mainland China and USSR are excluded)				
G. Castorbeans 1970				
Europe	25	20	8.0	Rumania
(USSR	200	98	4.9)	USSR
So. America	277	272	9.8	Brazil, Paraguay, Ecuador
Asia	473	168	3.6	India, Pakistan, Thailand
(Mainland China	180	90	5.0)	China
Africa	96	40	4.2	Ethiopia, Sudan
No. America	36	25	6.9	USA, Mexico, Haiti

Table 3 — Average Grain Yields of Oil Seed Crops (1970 FAO Production Yearbook)

Crop Type	Average Seed Yields Highest National Averages (in 100 kg/ha)				Average Oil Prices in Europe 1970
	Geographic Regions				
	South America	Asia	Africa	No. America	Dollars per metric ton
Groundnuts	14.1 (Brazil)	23.5 (Turkey)	11.2 (Nigeria)	23.0 (USA)	$319
Sesame	6.9 (Colombia)	9.5 (Saudi Arabia)	11.8 (UAR)	8.3 (Mexico)	Not reported
Sunflower	8.5 (Argentina)	10.7 (Turkey)	6.7 (Morocco)	9.3 (USA)	$217
Safflower		(Not reported)		28.0 (USA)	Not reported
Soybeans	17.6 (Colombia)	14.8 (Taiwan)	8.6 (Nigeria)	20.8 (Canada)	$202
Cottonseed	10.5 (Colombia)	19.7 (Israel)	12.7 (UAR)	12.7 (Mexico)	$270
Castorbean	17.9 (Peru)	9.1 (Thailand)	11.4 (Sudan)	9.5 (USA)	$291

Table 4 Average Composition* of Mature Oil Seeds; for crops adapted to Tropical and Subtropical Regions

Crops	Moisture %	Oil+ %	Protein %	Carbo-hydrates %	Fiber %	Mineral Matter %
Cottonseed, whole seed	7.3	22.9	23.1	26.3	16.9	3.5
after oil extraction	9.0	2.0	41.6	31.1	10.7	5.6
Sesame, whole seed	8.0	42.9	22.3	10.9	10.3	5.6
after oil extraction	6.3	9.0	43.3	23.6	6.2	11.6
Safflower, whole seed	6.9	29.8	16.3	17.5	26.6	2.9
after oil extraction	6.2	1.0	21.8	40.1	26.9	4.0
Sunflower, whole seed in hull	6.4	25.9	16.8	18.8	29.0	3.1
after oil extraction	10.8	1.1	19.6	27.0	35.9	5.6
Groundnuts, seed without hull	5.4	47.7	30.4	11.7	2.5	2.3
after oil extraction	7.0	1.6	52.3	26.3	6.9	5.9
Soybeans, whole seed	10.0	18.0	37.9	24.5	5.0	4.6
after oil extraction	8.5	0.8	48.5	33.0	2.6	6.6

Castor beans - Toxic to animals and humans. Yields oil for industrial uses. The seed meal-castor pomace, is used for fertilizer.

Oil content of castor beans averages 35 to 55% of total weight. Castor pomace averages 5.2% nitrogen, 1.8% P_2O_5 (phosphorus), 1% K_2O (potash) and 0.75% Calcium plus Magnesium.

*Average analyses of crops grown in North America.

+Composition of cake or meal based on oil extraction by solvent process. Oil extraction by hydraulic or mechanical processes is usually less efficient, recovering less than 80% of the oil, so that the resulting cake or meal has higher oil content and lower protein content. The meal or cake is proportionately richer in calcium, phosphorus and other minerals than the whole seed.

Table 5
Part I

Imports of Vegetable Oilseeds & Products
(Imports by Mainland China and USSR not included)

Imports of Unprocessed Oil Seeds - 1969

Importing Region	Quantity - Metric tons	Value - Equivalent US Dollars
A. Groundnuts, unprocessed		
Europe	2,013,380 tons	$435.0 Million
So. America	2,930 "	1.1 "
Asia	153,130 "	41.0 "
Africa	27,120 "	5.7 "
No. & Central America	84,980 "	24.6 "
B. Sesame seed		
Europe	75,908 tons	$ 16.90 Million
So. America	(Negligible)	(Negligible)
Asia	82,255 "	18.35 "
Africa	10,745 "	2.55 "
No. America	17,608 "	5.43 "
C. Sunflower seed		
Europe	467,176 tons	$ 63.98 Million
So. America	152 "	0.04 "
Asia	91,153 "	12.14 "
Africa	378 "	0.05 "
No. America	1,867 "	0.35 "
D. Safflower (unofficial data		
Total World exports 23,000 tons (1970)		$ 2.07 "
(Primarily from USA, but 6,300 from Canada in 1971)		
E. Cottonseed		
Europe	119,764 tons	$ 10.31 Million
So. America	113 "	0.04 "
Asia	294,402 "	22.54 "
Africa	4,983 "	0.37 "
No. & Central America (1968)	31,504 "	2.67 "
F. Soybean seed imports 1969		
Europe	5,462,236 tons	$565.59 Million
So. America	36,750 "	3.61 "
Asia	3,369,800 "	369.98 "
Africa	2,520 "	0.42 "
No. & Central America	440,450 "	42.88 "

Table 5 (con't)
Part I

Importing Region	Quantity - Metric tons	Value - Equivalent US Dollars
G. Castorbean seed imports 1969		
Europe	63,442 tons	$ 10.20 Million
So. America (1968)	1,444 "	0.21 "
Asia	51,403 "	7.70 "
Africa	1,602 "	0.28 "
No. America	(Negligible)	(Negligible)

Table 5 (con't) Part II — Imports of Vegetable Oils, 1969

Importing Region	Quantity - Metric tons	Value - Equivalent US Do
A. Groundnuts oil		
Europe	336,363 tons	$107.18 Million
So. America	3,784 "	0.98 "
Asia	27,271 "	10.75 "
Africa	12,224 "	4.64 "
No. & Central America	10,250 "	3.20 "
B. Sesame oil		
Not reported		
C. Sunflower seed oil		
Europe	683,454 tons	$147.99 Million
So. America	56,915 "	12.14 "
Asia	46,642 "	10.25 "
Africa	84,284 "	19.47 "
No. & Central America	69,382 "	15.75 "
D. Safflower		
Not reported		
E. Cottonseed oil		
Europe	44,057 tons	$ 11.81 Million
So. America	38,784 "	11.05 "
Asia	22,597 "	7.20 "
Africa	17,638 "	6.38 "
No. America	10,323 "	2.59 "
Cent. Amer. & Carrib.	17,933 "	6.12 "
F. Soybean oil		
Europe	176,198 tons	$ 35.56 Million
So. America	51,588 "	11.82 "
Asia	270,622 "	75.31 "
Africa	121,001 "	25.56 "
No. & Central America	44,478 "	11.41 "
G. Castor oil imports, 1969		
Europe	115,680 tons	$ 33.76 Million
So. America	548 "	0.26 "
Asia	4,067 "	1.26 "
Africa	1,378 "	0.73 "
No. & Central America	73,362 "	17.97 "

Table 5 (con't) Part VII — Vegetable oilseed Cake & Meal, 1969

Importing Region	Quantity - Metric tons	Value - Equivalent US Dollars
A. Groundnut Cake & Meal		
Europe	1,102,000 tons	$108.03 Million
So. America	Nil	Nil
Asia	93,420 "	9.11 "
Africa	18,930 "	2.03 "
No. & Central America	Nil	Nil
B. Sesame Cake & Meal		
Not reported		
C. Sunflower Cake & Meal		
Europe	513,690 tons	$ 40.91 Million
So. America	Nil	
Asia	Nil	
Africa	Nil	
No. America	Nil	
D. Safflower		
Not reported		
E. Cottonseed Cake		
Europe	1,265,230 tons	$ 94.32 Million
So. America	Nil	Nil
Asia	19,760 "	1.41 "
Africa	Negligible	Negligible
No. & Central America	40,030 "	1.35 "
F. Soybean Cake & Meal		
Europe	3,345,070 tons	$333.00 Million
So. America	Nil	Nil
Asia	78,290 "	8.11 "
Africa	2,550 "	0.25 "
No. & Central America	281,760 "	28.03 "
G. Unspecified types of oilseed cake & meal		
Europe	695,780 tons	$ 47.60 Million
So. America	Nil	Nil
Asia	190,840 "	13.26 "
Africa	2,590 "	0.61 "
No. America	3,500 "	0.21 "

Table 5 (con't)
Part III

Importing Region	Quantity - Metric tons	Value - Equivalent Dollars
H. Total oilseed cake & meal imports		
Europe	8.84 Mil. tons	$794.0 Mil
So. America	0.77 " "	0.9 "
Asia	0.46 " "	37.7 "
Africa	0.50 " "	4.5 "
No. America	0.28 " "	24.0 "

B. Sesame. (Sesamum indicum)

Uses

Whole sesame seed is used as of food crop; it is a prime source of oil for cooking or illumination; and the meal is a high-protein food. It has been under cultivation for many centuries in Asia and Africa. It requires no machinery for growth or harvest, and while considerable hand labor is required for such production, this may not be a serious limitation in developing countries. Virtually all of the world trade is in the form of whole seed. Locally, oil is extracted from the seed for use in cooking and as a food dressing, and the resulting cake or meal is used as food.

It is probable that the shattering losses at harvest time when mechanization is undertaken for plantation production, is responsible for the comparatively lower yields of seed that have been reported. Reported yields of seed per hectare are about equal to sunflowers, but substantially lower than for groundnuts, soybeans, and cottonseed. The average prices for whole seed of the crops, as reported from producing countries in 1969, was:

Sesame	- $216 per M.T. (naked seed)
Groundnut	- $195 per M.T. (35% hull)
Sunflower	- $126 per M.T. (45% hull)
Cottonseed	- $65 per M.T. (35% hull, linters and waste)
Soybean	- $98 per M.T. (naked seed)

The development of non-shattering types of sesame, as undertaken in the USA and Venezuela, would make the crop more attractive as a commercial oil seed crop in other regions.

World Production

Asia and Africa are major regions of sesame production, with minor centers in Central America and the southern portion of North America (See table 2).

Yields of seed per hectare are much higher in Central America and in Venezuela and Colombia, than in Asia and Africa. This is probably because of more skillful application of technology, than to any natural adaptation of the crop to ecological conditions. The highest average yields for individual countries in 4 geographic regions are reported in table 3. Of these 4 countries, the crop is grown predominantly as an irrigated crop in Saudi Arabia, United Arab Republic and Mexico, but is grown mostly with natural rainfall in Colombia. Under suitable growing conditions in the United States, yields of 2000 kg/ha have been produced. This suggests that the actual productivity potential of sesame may be comparable with that of other oil seed crops, when available technology is effectively applied.

World Trade

Sesame seed is a major import in 4 continents; - Asia, Europe, North America and Africa (See table 5). In Asia the major importers are Japan, Mainland China, Jordan, Hong Kong, Israel, Saudi Arabia, Malaysia and Taiwan. In Europe, the major importers are Italy, West Germany, Greece, Portugal, Poland and Denmark. The United States is the principal importer in North America, and the United Arab Republic in Africa. There are no statistical reports of imports of sesame oil or cake in world trade, implying that sesame moves almost entirely as seed.

Description

Sesame (also known as "benne" or "bene") belongs to the plant family "Pedaliaceae". It is an erect annual and individual varieties range from $\frac{1}{2}$ to $1\frac{1}{2}$ meters in height, and have from 1 to many branches. It has tubular shaped flowers, pale rose to white in color, borne in clusters along the stems.

The lower flowers begin blooming in 2 to 4 months after seeding (depending on the variety), and blooming progresses up the stem until the upper flowers open. Maturity is reached in 3 to 5 months after planting, depending on the variety. After seeds are fully filled, the upright pods, clustered in serrated ranks on the stem, lose green color and become dry. The tips of the pods then split open longitudinally, and the seeds drop out if the stalk is inverted. Prompt harvesting before the pods split open, and care in handling to present loss of seed is highly essential. The pods are many seeded; the seeds of different varieties are creamy white and yellow preferred in world trade. The seeds are about 0.4 cm long, slender, shiny, with a mucilaginous coating. The thin seed coat is rather easily split-off by abrasion, and the naked seed is rather soft and low in fiber. See table 4 for chemical composition of the whoel seed, and of the cake or meal after oil extraction.

Varieties

There are a great many varieties of sesame, but those of a particular geographic region tend to be similar. Any effort to develop commercial sesame production should include field testing of all improved varieties that are available from collections *made by other countries and research institutes; as well as the collection and testing of regional or local races of the crop.

*Consult the USAID Mission for information on the availability of seed from "World Collections" of sesame

Such field testing is essential to identifying varieties or races that yield well under local conditions, that exhibit resistance to insect pests and diseases, that have plant and seed characteristics favoring practical cultural practices, as well as market preferences on seed types. The limited number of available non-shattering selections may not be satisfactory in their present form for local use, but this trait may be incorporated in the other most promising varieties by appropriate breeding procedures using the non-shattering selections as one of the parents.

Ecological Adaptation

Sesame thrives in warm weather, and is grown very widely in the tropics and subtropics by selection of varieties that will grow and mature in some selected season of the year. As to rainfall, it is grown successfully, by using adapted varieties.

Moderate soil moisture in the seed bed is important at planting time to insure prompt germination and to avoid soil crusting that would prevent seedling emergence. Sesame will endure considerable moisture shortage during the vegetative growth period, but high seed yields require a fairly continuous soil moisture supply after flowering, until seed is filled. The earliest varieties will mature in 90 days after planting, and other varieties may require, as much as 120 to 140 days.

Soil preference are well drained, deep sandy loam or loam, with moderate fertility. However, the crop is capable of producing lesser yields on shallow soils, and on heavier textured soils if planting procedures succeed in producing a good stand of plants.

Double Cropping

Because of its relatively short growing season, sesame is suited to farming systems where double cropping is feasible. The limitation is the occurrence of sufficient rainfall during the period when sesame is to be grown. Under irrigation farming, sesame should fit rather well into the farming system where sufficient irrigation water is available. Sesame is a relatively low user of water, and it is capable of utilizing moisture left in the soil from the previous crop. However, some irrigation will be needed at planting time, and additional irrigation may be required at time of flowering to produce a seed crop.

Culture

Soil preparation for planting sesame is important, since the seed is small and should be planted in a mellow seed bed not deeper than 1 to 2 cm. Deeper planting risks poor emergence because of soil crusting; and placement in cloddy soil prevents many of the seed from making sufficiently good contact with the soil to imbibe moisture and support germination. Sesame responds to fertilization, particularly nitrogen and phosphate, and the fertilizer should be placed in bands within 2 cm of the seed but without direct contact and slightly lower than the position of the seed. The amounts of fertilizer should be adjusted to the fertility status of the soil, as determined by field trials. Applications of dung during seed bed preparation, or in bands above the planted row, will improve yields. If sufficient dung is applied, it may replace commercial fertilizer.

Sesame should be planted in rows about 30 cm. apart, to facilitate weed control and harvest. The amount of planting seed depends on the nature of the variety, the earlier maturing unbranched types may be spaced at 10 cm between

plants in the row, and larger branched types should be given greater space between plants. Planting should be adjusted to the season, to permit sufficient soil moisture for rapid germination, and for maturation and harvest in a period without excess rain.

Weed control is quite essential; and weeds should be pulled or removed by hoeing while still small, so as to avoid unnecessary injury to the sesame root system.

Harvesting should be carefully planned, to harvest the plants before the seed capsules split open and lose seed by shattering. The plants should carefully be tied in bundles, and put upright into shocks to dry. When completely dry, the bundles are merely inverted over a solid floor or canvas, and shaken vigorously to remove all of the seed. No machinery is required for threshing. The seed is smooth and easily cleaned of all trash by win owing.

C. Sunflower (Helianthus annus)

Sunflower seed is grown rather widely in the tropics and subtropics, but commercial production of those regions is concentrated mostly in Turkey and Ethiopia, with lesser amounts in Morocco and Tanzania. The species is native to North America, and substantial production occurs in Canada and the United States. However, production in Spain, U.S.S. R. and southeastern Europe far exceeds that of any other world region except Argentina and Uruguay. Despite the evidence from present production centers in the temperate zones, the crop appears to have substantial potential as an oil seed crop in many tropical and subtropical regions, having adaptation similar to maize, but with greater tolerance of drought, and also for high altitudes.

1. Uses

The seed is used directly for food by cracking the hulls to expose the naked kernels, either before or after roasting or cooking. The seed is high in oil - 30 to 35% (in contrast to about 20% for cottonseed); and the oil is edible and excellent for cooking, and it is acceptable for lighting. It is also used for margarine and food dressings. Sunflower seed cake produced by extraction of oil from the unhulled seed is an excellent high protein feed for ruminant livestock. See table 4 for average feed composition. The cake or meal from dehulled seed is an excellent protein food for man, and for non-ruminant animals. The nutritional value of the sunflower seed protein is exceptionally high for a protein of plant origin (see table 1.), but is somewhat deficient in the essential amino acid-lysine. Sunflower seed, and the oil and cake enter world trade extensively, with seed imports largely going to Western

Europe, and oil going to all continents.

2. World Production

Tropical and subtropical production of sunflower seed (in 1969) is shown in table 2. From the standpoint of potential production, the statistics fail to tell the full story. Smaller dispersed fields of sunflowers are not generally included in statistical reports, particularly when the crop is consumed locally, and when there are limited supplies in excess of current food needs that would enter market channels. There appear to have been no sustained and concerted programs to promote sunflowers as an important crop. The high nutrition value of the seed protein has not been emphasized, and there has been little attention given to application of improved technology of production. Sunflower seed as a versatile, edible oil and high protein market crop for the tropics and subtropis appears worthy of more intensive consideration.

3. World Trade

Table 3 gives the comparable prices of oil from six annual oil seed crops, using European market price in 1969. The major markets for whole sunflower seed were in Europe and North Africa (see table 5.) The average price per metric ton of seed was $137 in Europe, where Italy, West Germany, East Germany, Hungary and Czechoslovakia were the major

importers. Morocco was the major African importer, and the reported price was about the same as for Europe. Kenya also imported substantial sunflower seed.

Sunflower seed oil was imported by many countries, in all continents; but Europe was the major importer. The price paid for oil was about $216 per metric ton in 1969. Europe imported virtually all of the sunflower seed cake and meal that was marketed in world trade, at an average price of about $80 per metric ton. It is believed the cake and meal were imported largely for use as high protein livestock feed.

4. Description

The sunflower plant is a stout erect annual, varying in height from 2 to 6 meters for different varieties. It has rough hairy stems, the main stem (and any branches) terminating in disc-like heads, that may range from 5 to 30 cm across, depending on growing conditions and the variety. The head is actually a composite inflorescence, with many rows of fertile flowers arranged radially, and a rim of sterile ray flowers. The flowers are cross-pollinated largely by insects, and produce elongated seeds enclosed in a strong hull. The mature seeds vary in size and color with specific varieties. Colors range from white, to striped to black in different strains and varieties. The plant takes the name "sunflower" from the bending of the stem toward the sun during daylight hours, so that the heads and the leaves

tend to face east in the morning and follow the sun during the day, and face west at sundown. This following of the sun partially ceases after pollination. Advantage is sometimes taken of this movement, by planting rows north and south, so that harvest of heads is facilitated by cutting the overhanging heads on the east side of every row.

Varieties There are many named varieties and hybrids of sunflowers, developed and grown in the major world regions of production. This abundance of types has not been effectively exploited in undertaking to increase production of sunflower seed in the tropics and subtropics. Short-season varieties are suited to regions with short seasons of adequate rainfall, and longer-season varieties for regions with longer rainy seasons. Such varieties and types also differ in the depth of rooting, type of head, stem branching, seed type, and oil content. It is particularly important to make field evaluations of all available varieties and hybrids, to identify those with the greatest resistance to pests (insects, diseases, bird damage, etc.) as well as to any lodging of stems, and shattering of seed.* Some advantage may be taken of field evaluations of varieties and hybrids made in regions of similar ecological conditions, but there is no substitute for actual field testing under the conditions where the crop is to be grown.

Consult the USAID Mission for information on the availability of seed from "World Collections" of sunflower varieties and hybrids.

Ecological Adaptation

Sunflowers have a wide range of adaptation to both climatic and soil conditions. It thrives wherever maize is grown, but may also be grown successfully at high altitudes that are too cold for maize, and it tolerates as much drought as sorghum. The early maturing varieties will complete a life period in four months, and produce a normal crop if soil moisture is available throughout that period. Sunflower varieties or hybrids are grown widely in regions of limited or uncertain rainfall, but also have promise in moderately humid regions (1,000 to 2,000 mm. rainfall yearly.) Leaf diseases may be serious in regions of abundant rainfall, but this varies greatly with varieties.

The sunflower has wide soil adaptation, partly because of its deep and well branched root system that utilizes soil moisture to considerable depths. However, the crop also is a strong feeder for soil nutrients, tolerates relatively low fertility, but responds strongly to higher fertility levels.

Cultural Practices

Seedbed preparation for sunflowers should follow the best practices developed for maize. The usage of commercial fertilizers and of dung that are best for maize or sorghum, is applicable to sunflower culture. The crop responds strongly to higher levels of fertility, although it will make a smaller yield at lower levels.

The date of planting should be scheduled to take advantage of favorable soil moisture for prompt germination; but it is also important to plant a variety that will mature in a comparatively dry period. Sunflowers are best planted in rows about 1 meter apart, with plants 25 to 30 cm apart in the rows. The density of plants in the row must be adjusted to rainfall, and to the size of plants for the particular variety. Short-season varieties need less space per plant than longer-season types; but the best spacing to give maximum yields of grain must be determined by field trials in production areas. Six to ten kg. of sound seed should plant a hectare. Seed should be planted 2 to 4 cm deep; and fertilizer should be placed in bands within 5 cm of the seed, but at a somewhat lower level, to produce greatest benefits. Dung should be incorporated in the soil for best improvement in yield per unit of dung applied.

Weed control is quite important in production of sunflowers. This is particularly true if the crop is grown in a region of limited rainfall, or on soils of low fertility. Weeds should be killed while still quite small, whether by hoeing or pulling, to avoid damage to the sunflower plant root system. Heavy infestations of weeds may reduce yields by 50% or more.

Harvest of the heads may begin as soon as seeds are fully developed. Except for white seeded types, full coloration of the hull is an indication of maturity. Heads may be removed, and spread on a smooth area for sun drying, before threshing. Field curing of heads

left on the plant accomplishes drying but exposes the heads to bird damage, shattering, lodging of plants, and rain damage.

Storage of whole seed that has been well dried should provide for protection against insect and rodent damage, and maintain the seed in a dry condition to avoid molds and rots. Seed that is to be processed for oil should be processed promptly to forestall losses in storage.

D. Safflower (Carthamus tinctoris)

Safflower is a member of the compositeae family of plants and a distant relative of the sunflower. Species of this family have many flowers and seeds in each inflorescence. It is an ancient food and oil crop, grown primarily in Asiatic and Mediterranean countries where the climate is subhumid to semi-arid, or where there are prolonged dry seasons that are unfavorable for growing most annual crops. It has particular significance in such areas because of the wide usefulness of the seed; for direct use as a food, as a source of oil for both food and illumination, and for the nutritive value of the cake or meal that is the residue of oil extraction. The potential productivity of safflower on irrigated lands in hot, dry climates has only recently been evaluated; and it appears to be at least equal in value of the crop per hectare to wheat and barley.

In recent decades, the crop has attracted attention in the western areas and the Great Plains of the U.S.A. and adjoining regions of Canada. Improved varieties have been developed and studies made on the most productive cultural practices. World efforts on production of the crop now appear to come largely from the U.S.A. and Canada; and Japan is a major world importer. However, official statistical data are believed to be misleading, in that safflower seed, oil, and cake is doubtless included in data for sunflowers and its products, since the two seeds are similar in general appearance, and the processing and end products of the two crops are quite similar. It is reasonably clear however, that safflower is an acceptable oil seed for world trade

and that the real issue in evaluating safflower as a national oil seed crop is whether or not it will bring greater net returns than some other oil seed crop, or other crops that would fill the same place in farming systems.

Uses: Safflower seed averages 40 to 55% hulls; the smaller percentage being achieved where the crop is produced with an improved variety under favorable moisture conditions. Oil content of the seed also varies with yields, ranging from 22 to 34%, averaging about 32%. The meal derived from the naked kernels (dehulled seed) averages 42% total protein; and from unhulled seed--21% total protein. Meal from unhulled (naked) seed is a valuable protein feed for ruminant livestock, and horses, mules, and asses. More significantly, meal from naked seed is a high-protein food for man. In common with most other plant proteins, it is not ideally balanced in all of the essential amino acids content, but is deficient in lysine. It is a very useful extender of animal proteins (meat, milk, eggs, fish) wherever the animal proteins are in short supply.

The oil is edible, useful for cooking and food preparations, and also is acceptable for lighting. In world trade, safflower seed and its products have similar values and uses as sunflower. The principal difference is that safflower generally has a high percentage of hulls.

Production

In the United States, where most of the available data have been recorded, yields have been reported up to 3,000 Kg/ha, but only when improved varieties and cultural practices are used. The maximum productivity probably means little to the dryland farmer, who has no other oil seed crop to choose to meet his subsistence needs in a harsh climate. There is need to evaluate the application of modern knowledge and technology pertaining to dryland farming, for both adapted edible oil seed crops and of grain crops*.

The limited recorded data on production of safflower are reported in Table 2. The principal producing countries are Spain, Paraguay, India, Turkey, USA, Canada, Mexico, and Australia. Average yields of grain per hectare are not available, but authenticated yield records on large fields in the USA have exceeded 3,000 Kg/ha.

World Trade

The USA and Canada were the major exporters of safflower seed in 1971 and Japan was the largest importer. As noted earlier, it is probable that world trade in safflower seed and its products follows the same channels as sunflower seed and its products. The safflower seed is somewhat smaller and has a higher percentage of hull, but in other respects, the two seeds are similar in uses and values.

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*See Technical Paper No. 4, "Improving Farm Production in Tropical and Subtropical Regions of Limited Rainfall", issued Nov. 1971 by Office of Agriculture, Bureau for Technical Assistance, U.S. Agency for International Development, Washington, D.C., U.S.A.

It is probable that safflower seed that enters the markets in much smaller volume than sunflower seed, may be combined with sunflower seed as it enters major markets. The oil and oil cake may also be combined with sunflower seed oil and cake, except where special markets call for safflower seed oil and cake.

The world total trade in safflower seed has been estimated at 745,000 metric tons in 1970 and 970,000 metric tons in 1971. The 3 largest exporters were Mexico, USA, and India in 1971; accounting for about 97% of the total reported.

Only about 20,000 tons of oil of the safflower seed was specifically reported for 1971 and only 3,000 metric tons of this was exported as oil.

Description

The safflower plant is an annual erect herb that grows 30 to 90 cm tall, branched at the top with white or yellowish smooth, pithy stems and branches. The flower heads are globular, $1\frac{1}{4}$ to 3 cm in diameter, with white, yellow, orange, or red florets. The leaves and outer floral bracts of the plant bear short spines, making the plant a typical thistle in general appearance. However, the seed is smooth, obovoid in shape, four-angled, white, or cream-colored, resembling a small sunflower seed.

Varieties*

Improved varieties have been developed in the major producing countries that are high yielding, adapted to specific regions, and with particular plant and seed characteristics. Some of these have plants that are spineless, or nearly so. There are great differences between varieties. In addition, collections have been made of regional types in the Near East, the Indian sub-continent, North and East Africa. The regional types may be the most useful in selecting for disease and insect pest resistance in specific countries.

Adaptation

In general, safflower is best adapted to sub-humid and semi-arid regions where it is grown in the short seasons when rainfall is likely to be adequate for crop production; and in irrigated fields in such regions. Safflower suffers severely from diseases in more humid regions. However, it grows well in regions of monsoon climates, as a crop planted at the end of the rainy season, that makes its growth and matures in the dry season. The best yields are made when the weather is hot and dry during the blooming period, but with adequate soil moisture still present. The average growing period ranges from 3½ to 5 months depending on the variety.

The crop prefers soils of average to good fertility. However, soil depth and soil water storage appear to be more important than soil fertility in the climatic regions where safflower is grown successfully.

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*Information on collections of seed varieties and regional types may be obtained from the USAID Missions in less developed countries.

Culture

Safflower does not compete well with weeds and it should be planted in rows to facilitate weed control. Seedbed preparation and cultural practices are similar to most of the grain crops. About 20 kg/ha of seed is required when planted in rows 75 to 90 cm apart, to give spacing of about 10 to 12 cm between plants. In the USA and Canada, the crop is often grown in drilled rows, 15 to 20 cm apart and such planting requires about 40 kg of seed per hectare. There is no tillage for weed control on drilled plantings.

Weed control is quite important for good yields of safflower. Particularly on plantings made on dryland (no irrigation), it is essential to control all weeds while still quite small, to avoid competition of weeds with safflower plants for the limited supplies of soil moisture. Weed control may be achieved by pulling, tillage, or use of herbicides, but should be achieved with minimum damage to the safflower root system. Regeneration of damaged root systems of safflower is very limited in dryland farming and lower yields result from any injury to roots.

The crop is ready to harvest when seeds are hard and dry. The crop does not lodge, the seeds seldom shatter, and bird damage is reported to be light. Hence the mature crop can be allowed to stand until harvest may be done conveniently. The seed is removed from the head in the same manner as for sunflowers. Safflower is

well suited to mechanized harvest and threshing, using machinery suited for wheat and barley with suitable adjustments. However, hand harvest and threshing has been traditional in Southeast Europe, Africa and Asia for many centuries. The improved varieties that are nearly spineless would make the crop much more attractive where hand harvest is practiced.

E. Cottonseed (Gossypium species)

Although cotton is grown primarily for the fiber, cottonseed as a by-rpoduct is an important world crop. In general, the seed cotton crop is composed of about one-third by weight of lint, and two-thirds of seed. When production is reported in terms of bales of cotton weighing about 500 lbs. each, there is a crop of about 1,000 lbs. of seed for each bale produced. The seed coat (hull) accounts for about 30% of the seed weight, the fuzz or linters 5%, naked kernels 60%, and waste or trash 5%. Cottonseed, and its products -- cottonseed cake and meal, and cottonseed oil enter widely into world trade. Because of the higher value of the lint per hectare, cotton is never grown as an oil seed crop, as are the other species included in tropical oil seed crops.

Uses

Cottonseed cake and meal is a high protein feed for livestock, and the meal produced by oil extraction may be used as an important protein food supplement for man. The nutritional value of cottonseed protein for human diets is shown in table 1, and the feed value for livestock is shown in table 4. Although total protein content is high, cottonseed protein is deficient in methionine and cystine, the sulfur containing amino acids. For feeding ruminant livestock, this is not a limitation, since these animals synthesize balanced proteins in the rumen.

For human food, and for feeding pigs and poultry, cottonseed meal is treated to remove or inactivate gossypol that is/toxic substance present in all cottonseed. Such treatment is not needed when the cake or meal is fed to cattle, sheep or goats, since these animals are not affected by gossypol.

With modern processing equipment cottonseed hulls are removed by machines, and the naked kernels are processed for oil. Normally, the cottonseed cake and meal entering commercial trade channels is of this type. However, in some areas "whole-pressed" cottonseed cake is produced without removing the hulls. This latter type of cake has lower feed value, averaging only about 28% protein (versus 43%) and 25% fiber.

Cottonseed oil is classed as a semi-drying oil, and is widely used for making margarine, and as a cooking oil.

Processing Cottonseed

The efficiency of oil extraction is greatest when the solvent method of extraction is used. The low temperature, hydraulic press method is relatively inefficient, and some of the high value oil is left in the cake which has a much lower value. For the European market in 1969, cottonseed was priced at $86 per metric ton, oil at $268, and cake at $75 per ton. The losses from inefficient extraction of oil are illustrated by the following data:

One metric ton of cottonseed in the hull, should yield about 200 kg. of oil and 800 kg. of cake, using the solvent process of oil extraction. With the low temperature, hydraulic press extraction, the oil yield may be as low as 160 kg. per ton; the remaining oil being left in the cake.

For naked seed (hulls removed), using the more efficient solvent extraction method, one metric ton of naked seed may yield 330 kg. of oil and 670 kg. of cake. With inefficient oil extraction by hydraulic press, the oil yeild may be as low as 265 kg. Not only does the cotton producer lose income in proportion to oil left in the cake, but the cake itself is lower in protein, and therefore less valuable as feed than cake that is well processed.

World Production

In recent decades, commercial cotton production has become widely distributed as a cash crop, as shown by table 2. Although lint (fiber) makes up about one-third of the weight of the seed cotton crop, and seed makes up about two-thirds, the lint on each hectare has a market value about four times as great as the accompanying seed. Thus, the production of the crop is determined by the value of lint produced, and the seed is a by-product. The higher value for the lint tends to mask the actual value of the seed crop.

Production in Europe is concentrated in Greece; in South America, Brazil, Colombia and Peru are the major producers; in Asia, the principal countries are India, Pakistan, Turkey, Syria and Iran; in Africa, the principal cotton growing countries are Uganda, United Arab Republic, Sudan, Tanzania, and Nigeria; while in North America, the United States and Mexico are predominant.

Economy of production has become quite important in determining the place that cotton has in farming systems. In view of the keen competition for world markets for the lint, full use should be made of the cottonseed and its products, to make the total cotton crop more profitable.

The highest average country yields of cottonseed are given in table 3. These yields are two to four times as high as the average for all cotton growing countries reported in table 2. Mexico, UAR and Israel produce cotton under irrigation, but Colombia grows much cotton with natural rainfall. While proper use of irrigation water is essential to high yields per hectare, it seems probable that the application of modern technology on other aspects of production also are important. The average yields reported in table 2, do not represent the potential productivity of cotton, but rather reflect the low general level of applying well known technology.

World Trade

The most important importers of unprocessed cottonseed are in Asia and Europe. See table 5. For cottonseed oil, Europe and South America are major importers. Europe takes the lion's share of cottonseed cake sold on the world markets. Cottonseed cake is a major protein feed for livestock in Europe. Since Europe actually has no shortage of either meat or dairy products, and the less developed countries that export cottonseed and cake are seriously deficient in animal protein for human diets, it would seem logical that much of the cottonseed and cake should be retained in the less developed countries. Export of high value cottonseed oil might well be expanded by processing all seed in the country where the crop is grown, and retaining the cottonseed cake for local use, either human food or for feeding ruminant livestock.

Description

Cotton belongs to the Mallow family of plants. The commerical varieties have been derived by selection and crossbreeding of four different botanical species; Upland cotton - Gossypium hirsutum
American-Egyptian Cotton - Gossypium barbadense
Asiatic Cotton - Gossypium arboreum and Gossypium herbaceum

These species exhibit considerable variation in length of fiber, and fiber strength and fineness, as well as plant and boll characteristics; so that the improved varieties developed by breeding have produced fiber (lint) of the type and quality desired in world markets. Breeding for higher yield has been a major objective in the world cotton growing regions. Great advances in these respects have been made in recent decades.

Cotton behaves as a warm season annual, although it is possible to grow a second crop on regrowth from the stubble after the first growth is harvested. This is termed the "ratoon" crop, and has never been as productive as the first growth. The plants of commercially important varieties are herbaceous, grow to heights of 60 to 160 cm. depending on the variety, and each plant has a main stem from which several to many branches arise. At the base of each leaf there are two latent buds, one of which may produce a vegetative shoot, and the other which may produce a flowering branch. The flowers are arranged on alternate sides of the fruiting branch, and there are three relatively large bracts (modified leaves) at the base of the flower, which enclose it in the bud stage. Flower colors may range from white to yellow to purple in various types, and the full color is usually developed a day or two after opening of the blossom. The fruit is known as a "boll", and it develops after pollination of the

blossum, into a three to five-celled capsule, $3\frac{1}{2}$ to 5 cm. long. The boll usually splits open at maturity, exposing the seeds covered with lint hairs (fibers) that may be 1-3/4 to 5 cm. long (depending on variety) when combed out from the seed. Depending on the variety, flowering begins 8 to 11 weeks after planting, and the individual boll will mature in 6 to 8 weeks thereafter. In the so-called "storm-proof" varieties, the expanded locks of intertwined fiber and seed in each cell of the boll do not fall out and are retained in the opened boll for some weeks. Since the blooming period may last from two to several weeks, ripening and opening of the bolls also occurs over an extended period. Retention of the locks in the opened boll makes it possible to harvest the crop in only one or two pickings.

The cotton fibers are slender, single-cell hairs growing out from certain epidermal cells of the cotton seed. The individual fibers lengthen for about 20 to 25 days, and the cell walls thicken for a similar period, before the boll opens. Unfavorable growth conditions (limited soil moisture, etc.) results in fibers of poor quality. Normally there are 27 - 45 seeds per boll. The seed coats are dark brown to black; and at maturity the seed coat constitutes 25 to 30% of weight of the seed. The oil content of the dehulled kernel averages 32 to 37%, being higher when there is adequate soil moisture during growth of the bolls. Mechanical delinting of the seed is frequently done at the oil seed mills, to prepare seed for planting.

Improved Varieties

Breeding programs to develop improved varieties have been actively pursued by all of the major cotton growing countries for many

decades. The characteristics that have received the most attention are adaptation to regional conditions, yield and quality of lint, resistance to insect pests and diseases, and harvesting traits. Comparatively little attention has been directed to any of the seed characteristics, although some efforts have been made to develop varieties that have a low content of Gossypol in the seed.

For countries that wish to maximize the potential returns from seed and its products, it would be useful to make field trials of all promising varieties* to determine not only the lint yield and quality, but also the seed yield and oil content. Where lint yield and quality would not be sacrificed, those varieties with superior seed yields should be given careful evaluation.

Ecological Adaptation

Mean temperatures of 77° F. (25°C.) or above during the growing season are essential for cotton to grow and mature a crop satisfactorily. The shorter season varieties of upland types require five months for growing and maturation, but most other types require six months or longer. Cotton also requires fairly abundant soil moisture, particularly from blooming onward, and abundant sunshine.

Cotton grows well on moderately fertile soils; but is grown successfully over a wide range of soil textures, from sands to heavy clays, and from moderately acid to strongly alkaline soils. Because of its heavy use of water, deep soils that have good moisture holding capacity,

*Consult the USAID Mission for information on collections of improved varieties, and the acquisition of seed for field trials.

and that favor deep rooting of the crop, are the more productive cotton soils. A shortage of soil moisture from blooming onward often results in dropping of young bolls, and stunting of the remainder, with sharply reduced yields as the result. Ideally, cotton prefers occasional rains to replenish soil moisture, accompanied by an abundance of sunshine. Much cotton is grown in irrigated areas, where sunshine is plentiful, and water can be supplied as needed. Water requirements for cotton are heavier than for most other crops, and this water consumption is particularly high in regions of low air humidity.

Cultural Practices

Cotton is often planted on ridges or beds in regions of heavy rainfall, but level or furrow planting is practiced in regions of moderate to low rainfall. Higher yields are largely dependent on adequate use of fertilizers that carry nitrogen, phosphate and potash. The amount of fertilizer and the relative proportions of nitrogen, phosphate and potash may be estimated from soil testing in the laboratory, but field trials are needed to actually measure the benefits. In general, the fertilizer should be placed in bands about four to five cm. away from the seed, but somewhat below it, to avoid possible injury to germinating seed, and to supply nutrients early in the growth period.

Cotton seed is usually delinted for planting, to cause it to germinate more promptly, particularly if there is any danger of low soil moisture at planting time. Seed is planted three to four cm. deep, at the rate of 30 to 40 kg. per hectare, in rows about one meter apart.

Cotton suffers from weed competition, and weeds should be killed while still small, whether by hoeing or pulling, or use of herbicides so as to avoid damage to the cotton root system. Weed competition may reduce yields as much as 50%, and also impair crop quality.

Cotton picking must be adjusted to the ripening process, particularly if the varieties being grown tend to drop the locks soon after they open. Picking every week or ten days may be necessary to avoid losses, in the event of storms during the harvest period. The storm-proof varieties may reduce frequency of picking to a mid-harvest and a final picking.

F. Soybeans in the Tropics and Subtropics

The soybean is one of the oldest of cultivated crops; cultivation in China has been authenicated as early as 2838 B.C. It continues to be a major food crop in China and other temperate zone regions of Asia; and has reached its greatest development as an industrial crop in the temperate zone of North America, particularly the U.S.A. Soybean production has spread southward from China to Indonesia; and has become a crop of some significance in southern Brazil. Although soybeans have about the same ecological adaptation as maize, the production of soybeans has followed maize only in the United States. This may be explained by the fact that maize is a prime food crop for man, whereas mature soybeans are low in digestibility when cooked in the home under normal conditions. In the orient, they are converted into excellent food by sprouting or fermentation. Only in recent decades was it learned that heating to relatively high temperatures, as is done in modern processing to extract oil, inactivitates the inhibitors to digestion, so that soybean meal is an excellent high protein food. Methods are now being explored for developing a procedure that is feasible for cooking soybeans in the home. This would make them competitive with food grain legumes as a foodstuff.

As a general rule, soybeans are very sensitive to the length of day for the principal production regions of the temperate zones. There is no doubt that selections or varieties of soybeans can be developed for tropical and subtropical regions that have daylengths of 12 to 13 hours; and when such varieties become available, soybeans

may become a prime industrial crop for such regions.

Uses

Soybean grain has two major uses -- for oil and for oil meal. In the U.S.A., where soybeans are a major crop, 90% of the crop is crushed to obtain oil, and the resulting oil meal is a by-product. The solvent process for extracting oil is more efficient than the older expeller and hydraulic press processes, and has largely replaced them. The older processes produced meal containing 5 to 6% oil, but their oil content is reduced to 1% or less by the solvent process. Whole soybeans average 18% oil (see Table 4.) and 38% protein. Oil meal averages 48% protein; and it is recognized as a high quality protein feed for all classes of livestock. With very little additional processing, it is a highly acceptable protein food for man. As shown in Table 1., it is deficient in the nutritionally essential amino acid - methionine (and Cystine), and must be supplemented with other protein (milk products, meat, fish, eggs) to provide a balanced protein food for human use. Although plant proteins are all somewhat unbalanced nutritionally, they may be regarded as useful extenders to animal proteins thatare universally deficient in less developed countries.

Soybean oil is an edible oil, well suited for manufacture of margarine for cooking, for a variety of food preparations, for illuminating in rural regions, and for a wide variety of industrial uses. As a foodstuff, soybean oil is directly competitive in uses with other edible vegetable oils. See Table 3., for comparative prices paid for edible vegetable oils in the European market in 1969. Soybean oil was priced at $202 per metric ton, groundnut oil at $319, sunflower oil at $217, and cottonseed oil at $270.

World Production

North America is the giant in present day soybean production (excluding Mainland China), producing 85% of the world crop. Asia produces sizeable amounts, mostly in Indonesia and Korea. South America follows, with most of the production in the southern temperate region of Brazil. Most of the soybeans in North America are produced in U.S.A., where production is completely mechanized. See Table 2.

Average Country Yields

The average country yields reported by FAO for 1970 show rather definitely that high yields are feasible in many countries. In contrast with an 1800 Kg/ha. yield in the U.S.A., the yields in the most productive country on each continent were: Colombia - 1760; Taiwan - 1480; Nigeria - 860; and Canada - 2080. See Table 2.

World Trade

The major importing regions for soybean grain are Europe and Asia. West Germany, Spain, Netherlands, Italy, Denmark, United Kingdom and Belgium all are heavy importers in Europe. Japan and Taiwan are the major importers in Asia.

For soybean oil, Asia predominates but Europe and Africa also import large amounts. Pakistan, India and Iran are major importers in Asia. West Germany, United Kingdom, Sweden, France and Netherlands are heavy importers in Europe. In Africa, the United Arab Republic and Tunisia predominate in imports. However, the world trade in oil is far smaller than that for whole seed.

Over 90% of the soybean cake and meal in world trade goes to Europe. West Germany and France are the heaviest importers, but West Germany, Italy, Denmark, and Belgium also import substantial tonnages. Trade in soybean cake and meal is nearly 10 times as great as for oil, but only about one-half as great as for whole seed.

Description:

The soybean (Glycine max) is a member of the legume family; and when well inoculated with root nodule bacteria is capable of meeting all of its nitrogen requirements without benefit of nitrogen fertilizers. The soybean is a warm temperature annual, that is usually erect in growth habit, bushy and rather leafy. Varieties differ in height, from about 40 cm. in early types to 120 cm. for late maturing types. The amount of branching also increases in longer season varieties. The soybean is determinate in habit -- blooming, pod formation, and maturation are specific stages of development each affecting all parts of the plant simultaneously. As maturity approaches, the leaves turn yellow, and usually drop off before the pods mature. The plant has a branched tap root.

Flowers are quite small, white or purple, borne on short stems arising from stem nodes; and flowering proceeds rapidly from base to tip of the plant. The pods are small, straight or slightly curved, covered with hair, and contain one to four seeds. Seeds vary with variety from round to elliptical, and in color from straw yellow to various shades of green, brown or black. Commercially important varieties are predominantly straw yellow. The plant is mostly self-pollinated, although some natural

hybridization may result from insect visitations by bees or thrips.

Varieties*

Numerous improved varieties have been developed in the major producing areas. Each variety has a specific adaptation to a region having a particular length of day during the growing season; but there are a relatively few varieties that are photoperiod insensitive, i.e., they are relatively unaffected by the changing length of day that typifies the temperate regions. Prime consideration has been given to yielding ability, non-shattering traits, seed quality, and oil content. Additional attention is given to resistance to prevalent soybean diseases and insect pests of the region where the crop is to be grown.

Since there are wide differences between varieties grown in the major producing regions of the world, any efforts to introduce soybeans into a new area should evaluate a considerable number of diverse types to identify the types most likely to be useful. Having selected such a type, it should be useful to make field trials of as many specific varieties or selections within that type, as may be available. The best of these may be put into production, or used as parents for a breeding program.

Ecological Adaptation

Soybean culture has traditionally been concentrated in temperate zones, and each variety grown in a locality is well suited to a particular situation as to the changing length of day for a specific region. Temperate zone varieties grown in the tropics flower and mature quickly without

* Consult the USAID Mission for seed collections of soybean types, varieties and selections that are available for conducting country field trials.

making the vegetative growth necessary for good seed yields. Certain strains or varieties are known that are not sensitive to length of daylight period, and these would be immediately useful in the tropics and subtropics. The soybean appears to be generally adapted to the climates of the tropics and subtropics, as to temperatures, sunshine and rainfall. Mean temperatures of 25 to 27° C. are preferred. In general, soybeans grow well in climates suitable for maize. However, combinations of high temperature and low rainfall are harmful; reducing both yields and oil content of the seed.

A critical period is that of seed germination. Excess moisture or drought at that period reduces the plant population, and subsequent favorable growing conditions do not compensate for poor stands of the crop.

Soybeans grow well on a wide variety of soil types, but are most productive on fertile loams. They are more productive than maize on soils of lower fertility, provided the proper root nodule bacteria are present in the soil from previous soybean crops, or the seed is inoculated with such bacteria before planting. Soybeans are somewhat tolerant of soil acidity; but are not productive on wet lands, shallow soils, or other soil conditions that restrict root development. The crop does not show striking responses to phosphate and potash fertilizers in the season of application, but does benefit strongly from such fertilizers applied to previous crops.

Cultural Practices

Preparation of land for planting soybeans should follow practices suitable for maize. Dung should be incorporated in soil for best effects, but substantial benefits come from surface application s. Laboratory soil testing may be used to determine phosphate and potash needs of field soils, but field trials to determine fertilizer requirements for maize may be used as a guide. However, soybeans do not need nitrogen fertilizer, provided seed has been effectively inoculated with the proper type of nodule forming bacteria just before planting.

Two methods of plant spacing are used in commercial soybean regions; they are planted in rows 15 to 20 cm. apart, as in wheat or rice, and are not cultivated during growth; or they are planted in rows about 75 cm. apart, and cultivated during the growing season to control weeds. Both systems produce about the same yields, if weeds are suppressed. Seed should not be planted deeper than 3 or 4 cm. to avoid failure of emergence due to soil crusting. Thirty to 40 kg. of seed per hectare are sufficient for 75 cm. row planting, and about three times as much for close spaced rows.

Weeds offer severe competition to soybeans, and greatly reduce yields if not controlled. Weeds should be removed while still small, by tillage or pulling, so as to avoid injury to the soybean root system.

The best protection against insects and diseases is to plant varieties that have been found to be resistant to the local pests. However, when large acreages are grown in any locality, it is probable that certain pests will multiply to the point that pest control measures will become necessary. The program of pest control must be selected to combat specific pests as they occur.

Harvest

The soybean crop is ready to harvest when seeds reach the hard dough stage, or as soon as leaf fall occurs. However, harvest may be delayed further until seeds are well dried on the standing stalk, if the variety is a non-shattering type. Field harvesting-threshing is customary in mechanized soybean production in the U.S.A., in which case seed is well cured on the plant before threshing. If cutting and threshing are separate operations, the plants may be cut after leaves drop, then cured in windows until seeds are thoroughly dried (below 15% moisture), and then threshed. Threshing machines used for wheat or other small grains may be adjusted to thresh soybeans, without appreciable damage to the grain.

G. Castorbean (Ricinus communis)

The castorbean is not a true bean; it belongs to the Euphorbiaceae family of plants. Neither the seed nor the oil is edible; the seed and the plant are toxic to man and animals. The oil has many uses in industry, and the oil cake (castor pomace) is primarily useful as a fertilizer. The crop is generally believed to be a native of Africa, but the wild forms also occur on the Indian subcontinent. It has been grown as a cultivated crop on a limited scale in the U.S.A. since early 19th Century, but has never become a major crop. Commercial production now occurs in 17 countries distributed over five continents; occupying 1-1/4 million hectares and yielding a total of about 700,000 metric tons yearly.

Uses

The castorbean crop is grown primarily for its oil content, the castor pomace is a by-product. The oil is a non-drying type that is readily modified by chemical treatment. It has a constant viscosity at high temperatures and thus is useful as a lubricant for machinery under those conditions. Modified castor oil is used in paints and varnishes to increase quick drying properties. Castor oil and its derivates also are used in hydraulic fluids, plastics, asphalt tile, certain exp .osives, electrical insulation, cosmetics, biodegradable detergents, nylon and other synthetic fibers, urethane, and as a purgative.

World Production - 1969

Castorbeans are grown in the warmer portions of the temperate zones, and in the tropics and subtropics. In general, the crop is most productive in the moderately humid to subhumid regions. It tolerates considerable drought, but suffers from leaf diseases in periods of high rainfall and high humidity. See Table 2. for production data.

The USSR and Mainland China are the largest growers of castorbeans, but these crops do not enter world trade in an appreciable degree. In Europe, Rumania is the principal producer. In South America, Brazil, Paraguay and Ecuador are major producers. In Africa, commercial production is largely confined to Ethiopia and Sudan; in Asia, India, Pakistan and Thailand predominate; in North America, the U.S.A., Mexico and Haiti are the major producers.

From the standpoint of average yields per hectare, the very great differences (from 260 Kg./ha. to 980 Kg./ha.) suggest that both the factors of natural adaptation and the levels of cultural technology employed, are involved. Average yields of 1250 Kg./ha. were achieved in Paraguay, 990 Kg./ha. in U.S.A., 910 Kg./ha. in Thailand, and 1140 in Sudan (under irrigation). It seems unlikely that the full effect of modern production technology has been demonstrated.

World Trade

Seed imports. The importers of castorbean seed are shown in Table 5., Part I.. The major markets in 1969 were provided by Europe (about 55%), and Asia (about 40%). West Germany, United Kingdom, France and Italy imported the greatest amounts in Europe. Japan was the principal Asiatic importer.

Castor oil imports. (Table 5, Part II)

Europe and North America were the principal importers of castor oil in 1969. France, United Kingdom, West Germany, Netherlands, and Czechoslavakia were the heaviest importers in Europe. The United States was a major importer in North America, with Canada and Mexico importing much smaller amounts. Japan was the largest importer of the Asiatic countries.

Castor Pomace. No FAO statistics are available on trade in castor pomace, but it is well known that its principal use is an ingredient in mixed commercial fertilizers. As noted in Table 4, castor pomace averages 5.4% nitrogen; 1.8% phosphate (P_2O_5); 1% potash (K_2O) and 0.75% lime (CaO + MgO.). The nitrogen is present in a slowly available organic form that is particularly useful in tropical soils. Also the phosphate appears to be substantially higher in effectiveness as a fertilizer than phosphorous in chemical fertilizers.

An approximate value may be placed on castor pomace, by calculation from the market prices of seed and oil. Assuming an oil content of the seed as 45%, and with beans priced at $160 per metric ton and oil at $290 per metric ton, the pomace may have a value of $40 per metric ton. The true price should be based on field performance of castor pomace as a fertilizer for crops, in comparison with results obtained from commercial chemical fertilizers.

A strong case could be made for extraction of oil by the producing countries, with exports limited to castor oil, and the pomace retained for use as fertilizer within the country.

Description

The castorbean is actually a short-lived perennial in the tropics and subtropics, but in most commercial production, it is handled as an annual. Different varieties grow four to 4 meters tall, but the shorter types are preferred for commercial production. The leaves are large, 10-30 cm. wide, and may vary in color -- green, purple or reddish. The greenish yellow flowers have no petals, and are borne in clusters (a raceme). Blooming is indeterminate, but varieties have been developed in which blooming is concentrated in a short period, so that ripe seed can all be harvested in a single harvest. Pistillate flowers are borne in the upper part of the raceme, and staminate flowers in the lower part. The seeds are borne in capsules, with one to three seeds each, and the capsules may be spiny or smooth. Smooth capsules are preferred in improved varieties. Wild forms forcibly eject the seeds at maturity, but most cultivated types retain the seed for an extended period. The obovoid shaped seed somewhat resembles a bean, and may be mottled, striped, or solid color.

The plant has a strongly branched tap root, that deeply penetrates the soil. The extensive root system is partly responsible for the plants tolerance of drought.

Varieties*

Improved varieties have been developed in several countries, to improve yields, and to establish uniform plant characteristics that facilitate production and harvest, such as short plant height, smooth seed capsules, and non-shattering habit. It is probable that much improvement could be made in the productivity of the crop in all regions by evaluation of the wide selection of improved varieties already available, and choosing those best suited to local conditions. Further improvement could be made by identifying desired traits in native populations, and using these in a well planned breeding program. Resistance to important insect pests and diseases is heritable, and may be introduced where needed, by a modern breeding program.

Ecological Adaptation

Castor beans grow over a wide range of climatic conditions, but the prevalence of molds that destroy the flower clusters, which is prevalent under humid conditions, has largely limited the crop to drier areas. In monsoon wet-dry climates, the crop is planted toward the end of the rainy season, and makes most of its growth on moisture stored in the soil. It produces well in subhumid to moderately humid regions, and under irrigation in arid regions.

The crop prefers a well drained soil, preferably loam, but

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* Consult the USAID Mission for information on seed of collections of improved varieties from various countries.

grows well on many other deep soils. It responds reasonably well to improved soil fertility but is less dependent on fertilizers than many other crops. Yields are more dependent on soil moisture storage than on other soil properties.

Cultural Practices

Seed bed preparation found desirable for maize, is recommended for castorbeans. It is probable that castorbeans will respond to applications of dung, and local field trials are recommended to determine responses to fertilizers under the soil conditions at hand. To facilitate weed control and harvesting of the crop, it should be planted in rows about 1-1/4 meters apart, with plants spaced 3/4 to 1 meter in the row. Planting in drier climates should begin as soon as sufficient moisture permits germination. Early plantings generally are more productive. Seed should not be planted deeper than 5 mm., to prevent poor emergence caused by soil crusting.

Weed control is quite essential, since weeds compete for soil moisture and nutrients. Weeds should be removed while still quite small, by hoeing or pulling, to provide control without damage to the castorbean root system.

Harvest should begin as soon as the seed capsules are dry, and continue as additional seed clusters ripen. A satisfactory harvesting method is to handstrip all of the pods from each fully ripe seed cluster, and collect the pods in a cotton-picking bag. Strong gloves must be

worn to protect the hands while stripping of the seed, if the variety is one that has spines. Penetration of spines into the skin will cause prolonged inflamation.

The pods must be dried by occasional stirring of shallow piles exposed to the sun (or under shelter if rains occur), until the seeds are fully dry. Special hulling machines are available, but hand flailing is commonly practiced, followed by winnowing to remove chaff.