OIL CROPS: SESAME AND SUNFLOWER SUBNETWORKS

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OIL CROPS:
SESAME AND SUNFLOWER SUBNETWORKS

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FOREWORD

In September 1989, the Sunflower and Sesame subnetworks held their bi-annual meetings in Cairo, Egypt. The meetings were well attended and papers, presented in these proceedings, provide a very informative overview of some of the cropping systems, management practices, production constraints and research highlights for both crops in several countries.

Chronic edible oil deficit is a major problem facing many developing countries in Africa and Asia where most countries are forced to import large quantities to satisfy the requirements of their growing populations. With the present rates of population increase and the improvement of nutrition standards it is likely that the consumption of edible oil will rise over the years, increasingly drawing on scarce foreign exchange for the importation of this vital food staple. For this reason, several countries have opted to increase self-sufficiency in edible oil.

Production deficits are due to a number of factors, among which neglect in oilcrops research, in both developed and developing countries has been a major one. This is particularly true for minor crops such as sesame. In the context of the IDRC oilcrops network, initiated in 1981, the interchange of information and the sharing of results between scientists have proved to be very useful and beneficial for the generation of scientific knowledge and the stimulation of research in this important area. It is hoped that conclusions and recommendations of this meeting will stimulate further research and development in the future.

A second important reason for limited national production has been the exceptionally low levels of world prices for oils and fats in the 1980's and the comparative advantage of importation over production for developing countries. The description of a case study using a system's approach to analysis the Vegetable Oil/Protein System of Kenya has stirred much interest during the Cairo meetings and it is hoped that similar work can be carried out in other countries in the future.

The Cairo meetings will also unfortunately be remembered as the one which has witnessed the diagnosis of the fatal disease of late Dr. Hiruy Belayneh, Chairman of the Brassica Subnetwork. We will all regret his absence.

On behalf of IDRC and of all participants, I would like to thank the Government of Egypt for its hospitality, the organizers for the excellent arrangements and all those who contributed to the success of these meetings by their presentations and discussions.

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SESAME GENETIC RESOURCES: COLLECTION, EVALUATION AND CONSERVATION

Amram Ashri

Abstract

Several expert consultations and various researchers dealing with sesame (*Sesamum indicum* L.) concluded that the existing germplasm collections of sesame should be expanded. This paper describes the germplasm collection of about 1650 accessions assembled by the author under the IBPGR grant and the data bases obtained from other investigators. The descriptors and states adopted are described and several new ones were added. The findings were computerized and the analysis of the data bases within and between locations is in progress.

Issues involved in the collection, evaluation, utilization, rejuvenation, and conservation of the sesame germplasm collections are discussed.

Germplasm resources constitute the evolutionary library of the species and are very important in plant breeding, evolutionary studies, botanical research, etc. Introduction has played a significant role in crop improvement since ancient times and still is; directly when introduced cultivars prove to be successful in a new region and are released to the farmers, or indirectly by hybridizing the introduced materials with local ones, transferring desired genes into the latter. This has been the case also with sesame (5).

Sesame germplasm collections have been assembled and studied over the years in several locations. Some were more comprehensive while others were more limited in scope. It should be noted that the first sesame germplasm collection was established in India in 1925 (14). Shortly after, a large world collection was assembled in the USSR (23). The very large sesame germplasm collections in India were described recently (22,19).

A very large collection has been studied and is maintained in the USA (17, 24, personal communication - G.A. White). Another very large collection has been assembled in Venezuela and is now being evaluated (personal communication - Ing. Agr. Helena Mazzani). Sizable collections of local and some introduced materials have been established and studied in R. of Korea. A large amount of collections were assembled and studied, mainly from evolutionary aspects by various workers (8,9,10).

Two FAO expert consultations (2,3) and the IDRC Workshop in 1985 (4) identified a pressing need to make a more comprehensive collection of sesame genetic resources, evaluate, utilize and conserve them. They recommended that the sesame germplasm collection, evaluation and exchange should be much enhanced, and appropriate arrangements for their long-term conservation be made. The IBPGR and FAO have acted accordingly and the IBPGR gave the author, in 1986, a grant to assemble the germplasm collection of cultivated and wild sesame species.

This paper is a progress report on the project. In 1988, 1645 accessions were sown in Rehovot (Israel) and data were collected for 14 traits. The analyses of the Israel data in the computer are in progress. Additional data were obtained from Dr. J.I. Lee on 600 lines for 38 traits and some data were obtained from the USDA (Dr. J.D. Mowder). These bodies of data will be analyzed separately and in comparison with each other when possible.

Materials and Methods

Assembling the germplasm collection

A large collection of germplasm was assembled, mainly in 1987 through an extensive effort including personal contacts, written requests and the assistance of investigators, national bodies - especially the USDA and the RDA of R. of Korea - and international ones especially the IBPGR, FAO and the IDRC Oil Crops Network. The germplasm collection was planted in the spring of 1988 at Rehovot, Israel (34° 5° E, 31° 5° N). The sources and numbers of the accessions are presented in Table 1.

In some cases, the contributing countries supplied only local materials, improved cultivars, and/or landraces and/or breeding lines. Often though, the source countries sent both local materials and accessions introduced into them. Thus, certain cultivars appear several times, e.g. the well known Venezuela and the U.S. varieties were obtained from their countries of origin as well as from several other countries. All were maintained as separate entities and will be compared to see if they are truly duplicate or if they have diverged over the years due to genetic shift or local selection pressures, out crossing and/or mixtures.

An examination of Table 1 shows that certain major sesame producing areas such as India, China, Burma and the Sudan are poorly represented. Actually, much of the Indian and Sudanese germplasm was included in the USDA collection, thus the representation of these gene-pools is better than that which appears in Table 1. The materials from mainland, China are poorly represented since not too many were included in the collections from other countries. Repeated requests for materials from other countries failed to secure shipments of seeds.It is hoped that the genetic resources of the countries that are poorly represented will be made available for international research cooperation soon.

Table 1. Sources of the sesame germplasm collections studied in 1988.

Source Country	No. of Accessions	Hebrew	Univ. Nos.
R. of Korea	407	1-401,	1581-1586
Bulgaria	25	402-424,	15779-1580
U.S.S.R.	5	425-429	
South Africa	5	430-434	
Kenya	5	435-438,	1643
India	6	439-444	
Thailand	15	445-450,	1628-1636
Sri Lanka	13	451-463	
Egypt	60	464-523	
Turkey	15	524-538	
Philippines	12	539-550	
Namibia	2	551-552	
Venezuela	22	553-568,	1637-1642
Burkina Faso	1	569	
Mexico	8	570-575,	1602-1603
Greece	32	576-607	
USA	937	608-1542,	1577-1578
F.A.O.*	51	1543-1576,	1611-1627
Japan	15	1587-1601	
Burma	5	1604-1609	
Nepal	1	1644	
Taiwan	2	1645-1646	
Total	1645		

*Includes 11 superior selections (8 non-shattering and 3 shattering) of Dr. D. Yermanos of the Univ. of California, Riverside, Central America, and materials from at least 8 countries.

Certain contributions of germplasm were received too late for inclusion in the 1988 nursery, notably a large collection from Dr. D.G. Langham and Mr. R. Langham of the Sesaco Corp. These are stored until another germplasm nursery will be grown.

So far, only the following wild species were obtained: *S. radiatum, S. alatum, Ceratotheca triloba* and four unknown entries (collected by contacts in Kenya and South West Africa). Much effort has been devoted to obtain wild species from their natural areas of distribution, mainly in West and East Africa. Unfortunately, the combination of lack of detailed information about the wild species and their maturation time and distribution, and of botanists, collectors, etc. made it very difficult to make progress.

Nursery and harvest procedures

The materials were sown in the spring of 1988, One 5 meter row per accession. The rows were spaced 1m apart, and plants were thinned to 20/m. At times the spaces were larger due to poor germination. The nursery was trickle irrigated throughout the season. Notes were taken as the desired traits became visible and/or at the appropriate phases during the season. The plants were let to flower and mature under open-pollination conditions. The extent of cross pollination is not known. Branches with mature capsules were harvested from all plants in each row, placed in large paper bags, allowed to dry and threshed. Seed characters were recorded on the cleaned seed samples.

Results and Discussion

General

The analysis of the data is in progress and the findings will be published when completed. Several more general points will be discussed here.

Descriptors and states

The descriptors and states developed under the auspices of the FAO and IBPGR (1) and the comments (7) served as a basis for the characterization of the germplasm collection. However, in several cases, they proved inadequate or too labor-consuming. The descriptors and states utilized in the 1988 nursery are described below; modifications are shown where such were made:

1. Date of first flower - later converted also to number of days from planting to flowering.
2. Plant height (cm)- mean of 3 measurements of typical plants per row.
3. Branching - a fourth state was added to those published (1): 1= None, uniculm, 2 = Basal branching (lower part of plant), 3= Top branching (upper part of plant) and 4= Basal and top branching (added).
4. Exterior corolla color, as in (1): 1 = White, 2 = White with violet / purple shading, 3 = White with deep violet / purple shading, 4 = Violet, and 5 = purple.
5. Number of flowers/leaf axil, a third state was added to (1): 1 = One, 2 = Three, and 3 = More than three (added).
6. Capsule shape, as in (1): 1 = Tapered, 2 = Narrow oblong, 3 = Broad oblong, and 4 = Square.
7. Number of carpels/capsule, as in (1): 1 = Two, 2 = MOre than two.
8. Capsule hairiness, changed from (1). It proved difficult to score separately the density and the length of the capsule hair as in the above. The following states combining length and density were utilized: 1 = Glabrous, 2 = Light, 3 = Medium, and 4 = Heavy.
9. Capsule length - Visual scores were used rather than measurements as recommended by (1) to reduce labor, as follows: 1 = Short, 2 = Medium, 3 = Long, and 4 = Very long.
10. *Alternaria* leaf spot: 1 = Immune, no symptoms, 3 = Resistant, very light infection, 5 = Medium, 7 = Susceptible, and 9 = Very susceptible.

11. Seed coat color - Examination of the seed coat color of all the accessions led to a revision of the available descriptors and states (1, 7). See Table 2.

12. Seed coat texture, as in (1) : 1 = Smooth, and 2 = Rough.

13. Seed size - To reduce labor, visual scores were used rather than weighing (1): 1 = Small, as HU No. 446 (Montalang from Thailand), 2 = Medium, as HU No. 700 (USDA PI No. 167343, origin - Turkey), and 3 = Large, as Ashri Line 1988-4127.

14. Seed lenght/width ratio, visually scored, as an approximation of seed shape: 1.0 = Ratio of 1.0, round, 1.5 = Ratio of 1.5, intermediate, and 2.0 = Ratio of 2.0, elliptic.

Forecasting performance and ranking

The traits studied can be divided into two groups regarding their response to the environment and/or the growing conditions: a) Unaffected - as corolla color or number of capsules/axil; b) Affected - as flowering time and plant height affected by day length and temperature, or degree of branching, which is affected by stand density and season.

For the characters which are not affected by the environment, a single entry in the data base should suffice. However, for those affected by the environment, multiple entries are required, denoting also the location, season, conditions, etc. Still, for the latter characters it is important to assess the forecasting value of the data from one location on the performance in another. This could be very important in breeding. For instance, can earliness or lateness in one test location be used to forecast flowering time in another? Or, if the oil content is affected by the locations' conditions, do the different accessions retain their relative ranking under different environments?

To investigate whether the oil content ranking is affected by the location, seeds of several hundred accessions from Korea, which were produced in Israel in 1988 were sent to Dr. J.I. Lee in Suweon, R. of Korea, for oil and protein content analysis. They will be analyzed with the same equipment and procedures that were used a few years ago to determine these values for seeds of the same accessions produced in Korea.

Preliminary findings indicate that the ranking of the accessions with regard to the length of period from planting to flowering is very location dependent, as would be expected. Therefore, evaluation inone location apparently cannot serve to pre-select a certain groupof "more promising" accessions for testing in a different region.
This point is being checked in detail for time of flowering, plant height and branching.

For environmentally-affected characters, comparisons of data from different locations and seasons could perhaps be aided by the establishment of an internationally agreed list of accessions which could serve as standards. The value of such standards will be examined by checking the data from Israel and S. Korea, and other data that may be available in relation to various reference groups of accessions. These groups can vary in number and make up.

Naturally, the analysis will be more valid if the data will be collected under the same conditions for all the accessions. It follows then, that for characters which show environment x accessions interaction; the data should be obtained in one season for

Table 2. Descriptors and states for sesame seed coat color.

		Ashri Reference Accession				Bartel & Goldberg**	
Code	Color	HU No.	Origin*	Source	Name or No.	Color	Reference Ac.
10	White	22	ROK	ROK	Gaesan	White	T-85
	Yellow						
21	Very light	87	ROK	ROK	Suweon 99	Very light yellow	Adi
22	Light	1258	Nepal	USA	PI 288854	Dark yellow	D-7-11-1
23	Medium	137	ROK	ROK	Yongan-1	Medium yellow	Zirra
24	Dark	107	Turkey	ROK	Anthalya-1	Very light brown	Margo short
25	Very dark	134	ROK	ROK	Gaeum	Light brown	Exute
	Grey						
31	Very light	60	Japan	ROK	Japanese black	Medium gray	Oro 9/71
32	Light	1587	Japan	Japan	No. 76, BON	--	--
33	Medium	618	Mexico	USA	PI 154, 300	Dark grey	Morada 67-11
34	Dark	648	China	USA	PI 158,056	--	--
35	Very dark	648	China	USA	PI 158,056	--	--
	Brown						
41	Very light	679	China	USA	PI 158,941	--	--
42	Light	700	Turkey	USA	PI 167,343	Medium brown	A-1-10
43	Medium	390	Japan	Japan	Black Wasegoma-2	Dark brown	A-5-13
44	Dark	633	China	USA	PI 158,038	--	--
45	Very dark	631	India	USA	PI 157,162	--	--
55	Black	239	NI	ROK	Tainan White		
				1-3-a	--	--	
	Reddish-rust (anthocyanin)						
61	Very light	892	Burma	USA	PI 202,725	--	--
62	Light	902	Japan	USA	PI 223,411	Very dark brown	X-30/46
63	Medium	--	--	--	--	--	--
64	Dark	--	--	--	--	--	--
65	Very dark	441	India	India	TMV 5	Anthocyanine	Gomi
	Green						
81	Very light	--	--	--	--	--	--
82	Light	1232	Venezuela	USA	PI 280, 809	--	--
83	Medium	--	--	--	--	--	--
84	Dark	--	--	--	--	--	--
85	Very dark	--	--	--	--	--	--

*Abbreviations, NI = Not indicated, ROK = Republic of Korea. **Their paper of 1985 (7).

all accessions, since conditions vary from year to year.

Differential geographical distribution of alleles

For breeding, it is important to identify geographical areas in which the frequencies of certain alleles are higher, e.g. alleles for resistance to a given disease. To this end, the frequencies of the different states of certain descriptors will be related to the areas of origin of the accessions. This study, though , is made more difficult by errors in recording the origins, mechanical admixtures or outcrossing.

Firmer answers to the above questions can hopefully be obtained from analysis of the Israel 1988 data and the data collected elsewhere.

Further collection needed

In a followup program to this project, much effort should be devoted to close the gaps in the germplasm collection of the cultivated species. These should include exploration and collection in poorly represented centers of diversity and obtain seeds from all existing collections. At the same time, the duplications in the collection should be eliminated. Thus, the collection could be enriched and still kept within a manageable size.

The obvious gap in the germplasm collection is the lack of wild species. There are 35 wild species in the genus (6, 12), most of them in Africa. The work carried out in Africa (20) concluded that it has limited genetic diversity in the cultivated species but it can be a good source of wild *Sesamum* germplasm. Special efforts should be devoted to the exploration, collection, evaluation and conservation of the wild *Sesamum* resources. This is important both from the breeding point of view and for evolutionary - systematic studies. It has been shown even by limited research that the wild species contain useful genes (13) which can be used to breed improved cultivars.

<u>Long-term maintenance of the collection</u>

Arrangements for the long-term maintenance of the collection are being made by the IBPGR and the author. The newly established and well equipped gene bank of the Rural Development Administration, Suweon, R. of Korea (Dr. Wan-Sik Ahn, Director) has been designated by the IBPGR as the first base collection for sesame. The author sent 30 of open-pollinated seeds (6000 - 7500 seeds) of each of the accessions to the Korean gene bank. The IBPGR is exploring other sites in order to identify a suitable location for a second base collection.

The long-term maintenance of the seeds may be supported by the finding that sesame seeds retain their germinability for about 5 years if kept in a well ventilated, dry room with ambient temperatures (21). It was also found that with lower temperatures sesame seeds remain viable longer; however, freezing temperatures were harmful. Research on optimal sesame seed storage conditions should be initiated without delay.

Rejuvenation of the collections posses problems too. Cross-pollination in sesame can sometimes reach 60% (6), depending mainly on insect activity. Thus, in periodic plantings of the collections to produce fresh seed supplies, precautions should be taken. Since insect elimination is impossible, selfing may be advisable. However, selfing by bagging is laborious and expensive and sometimes the seed obtained are few in number and poor in quality. Selfing may also contribute to genetic shift in the accessions, especially since many of them are not uniform and they should be kept that way.

Another possible avenue is to form pools from accessions which are genetically close and originated from the same region. This would reduce the number of collections to be maintained. Thus, it will be easier to grow them in isolation.

Still another approach to maintain the genes and alleles would be to create a few very large composite-cross gene pools, each adapted to specific conditions. This would be done by grouping many accessions, crossing them with a male sterile line and growing the bulked mixture of the hybrids for successive generations under the desired environmental conditions allowing them to intercross. This will be supported by segregation of male sterile plants. In this way, the alleles will be maintained and much new genetic variability will be generated, many new gene combinations will be formed. However, established genotypic combinations excelling in their performance may be lost.

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References

1. Anon. 1981a. Descriptors for Sesame. AGP: IBPGR/80/71. Intern. Board Plant Genet. Resources Secretariat, Rome.
2. ____ 1981b. Conclusions and recommendations. In, (A. Ashri ed.), Sesame and Safflower: Status and Potentials. FAO Plant Production and Protection paper 29, Rome:192-195.
3. ____ 1985a. Conclusions and recommendations. In, (A. Ashri ed.), Sesame and Safflower: Status and Potentials. FAO Plant Production and Protection Paper 66, Rome: 219-220.
4. ____ 1985b. Summary of Recommendations on the Oil Crops Network. In, (A. Omran ed.), Oil Crops: Sesame and Safflower. IDRC-MR105e. Ottawa: 247-251.
5. Ashri, A. 1988. Sesame breeding -- objectives and approaches. In: Oil Crops -- Sunflower, Linseed and Sesame. Proc. 4th Oilcrops Network Workshop, Njoro, Kenya, January 1988. IDRC-MR205e. Ottawa: 152-164.
6. ________ 1989. Sesame. In (Robbelen, G., Downey, R.K. and Ashri, A. ed.), Oil Crops of the World. McGraw Hill Publishing Co., New York: 375-387.
7. Bar-Tel, B. and Z. Goldberg, 1985. Descriptors for sesame -- a modififed approach. In: Sesame and Safflower -- Status and Potentials. (A. Ashri, ed.). FAO Plant Production and Protection Paper 66, Rome. 191-205.
8. Bedigian, D. 1981. Origin, diversity, exploration and collection of sesame. In, (A. Ashri ed.), Sesame and Safflower: Status and Potentials. FAO Plant Production and Protection Paper 66, Rome. 164-169.
9. Bedigian, D. 1984. *Sesamum indicum* L. : Crop Origin, Diversity, Chemistry and Ethnobotany. Ph.D. Dissert., Univ. of Illinois, Urbana-Champaign, IL.
10. _________ and J.R. Harlan, 1986. Evidence for cultivation of sesame in the ancient world. Econ. Bot. 40: 137-154.
11. Brar, G.S., and K.L. Ahuja, 1979. Sesame, its culture, genetics, breeding and biochemistry. Ann. Rev. Pl. Sci. 1: 245-313. Kalyani Publ., New Delhi.
12. Kobayashi, T. 1981. The wild and cultivated species in the genus *Sesamum*. In (A. Ashri ed.), Sesame and Safflower: Status and Potentials. FAO Plant Production and Protection Paper 66, Rome: 157-163.
13. Kolte, S.J. 1985. Diseases of Annual Edible Oilseed Crops. Vol. II. Rapeseed-Mustard and Sesame Diseases. CRC Press, Boca Raton, Fla.
14. Joshi, A.B. 1961. Sesamum. Indian Central Oilseeds Committee. Hyderabad-1, India.
15. Lee, J.I., and B.H. Choi, 1985a. Basic studies on sesame plant growth in Korea. In (A. Ashri ed.), Sesame and Safflower: Status and Potentials. FAO Plant Production and Protection Paper 66, Rome: 131-136.
16. _________ and ___________ 1985b. Progress and prospects of sesame breeding in Korea. In (A. Ashri ed.), Sesame and Safflower: Status and Potentials. FAO Plant Production and Protection Paper 66, Rome: 137-144
17. Massey, J.H. 1966. Preliminary Evaluations of Sesame Plant Introductions. Bulletin N.S. 181. Univ. Georgia, Col. Agric. Exp. Sta., Athens, GA. USA, 29 pp.
18. Osman, H.E. and D.M. Yermanos, 1982. Genetic male sterility in sesame: reproductive characteristics and possible use in hybrid seed production. Crop Sci. 22: 492-498.
19. Paroda, R.S., R.K. Arora, S. Singh, and T.A.

Thomas, 1987. Genetic resources of oilseed crops in India. In (A. Omran ed.), Oil Crops: Niger and Rapeseed/Mustard. IDRC-MR153e, Ottawa: 188-192

20. Rheenen, H.A. Van. 1981. Genetic resources of sesame in Africa: collection and exploration. In (A. Ashri ed.), Sesame and Safflower: Status and Potentials. FAO Plant Production and Protection Paper 66, Rome: 170-172.

21. _______________ 1981. Longevity of sesame seed under different storage conditions. In (A. Ashri ed.), Sesame and Safflower: Status and Potentials. FAO Plant Production and Protection Paper 66, Rome: 173-175.

22. Thangavelu, S., C.S. Sridharan, V. Muralidharan, and M. Suresh, 1985. Sesame breeding in the southern states of India and methods of evaluating breeding materials. In (A. Omran ed.), Oil Crops: Sesame and Safflower. IDRC-MR105e, Ottawa: 28-43.

23. Weiss, E.A. 1971. Castor, Sesame and Safflower. Leonard Hill, London: 311-525.

24. Yermanos, D.M., S. Hemstreet, W. Saleeb, and C.K. Huszar, 1972. Oil content and composition of the seed in the world collection of sesame introductions. J.Am. Oil Chem. Soc. 49: 20-23.