TRILOKI NATH KHOSHOO

(7 April 1927 – 10 June 2002)

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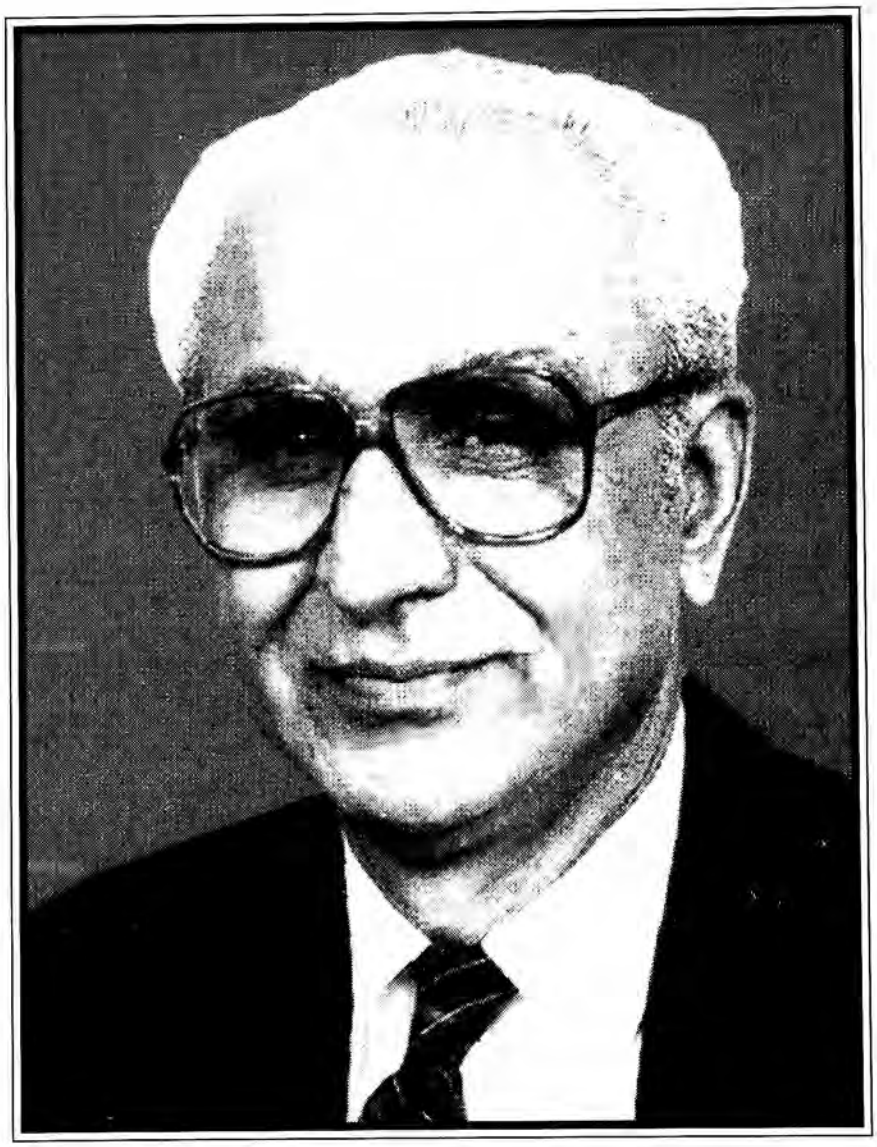

T. M. Khosloo

TRILOKI NATH KHOSHOO

(1927-2002)

(Elected Fellow 1978)

An excellent teacher, a celebrated researcher and an able administrator, Triloki Nath Khoshoo is known for his outstanding contributions in the field of education and research. The elucidation of genetic systems of conifers, crucifers, subsidiary food plants and ornamentals earned him a worldwide recognition. He was a unique environmental scientist and a thinker whose policies and action plans for eco-restoration of derelict lands, conservation and utilization of biodiversity, sustainable development and environmental management have been widely acclaimed and admired in India and abroad.

I. LIFE SKETCH

(a) Early Period

Khoshoo was born on April 7, 1927 in Srinagar, Kashmir valley. He was the fifth son of his parents and had three sisters also. All his elder brothers got good education and retired as high position officers. Their father, Pandit Sansar Chand Khoshoo was an employee of the Maharaja of Kashmir in the Customs Department (1885-1925). Beginning his school education in Baramula, young Khoshoo passed his matriculation in 1940 in first division and did his intermediate with Biology, Chemistry and Physics in 1942 from SP College, Srinagar securing the highest marks in Biology in the Punjab University, Lahore. For higher studies he went to Lahore (capital of the erstwhile Punjab State) and obtained his B.Sc. (Hons.) and M.Sc. (Hons.) degrees in Botany in 1945 and 1946 respectively from the same university. He did M.Sc. research under the able guidance of Late Professor PN Mehra who gave high ranking for his capabilities. The Government of Jammu & Kashmir selected Khoshoo for advanced training course in forestry at Edinburgh (United Kingdom). But with the accession of JK State with the Indian Union after Independence, the new state government cancelled the scheme of foreign education for youngsters.

(b) Later Period

Dr. Khoshoo was married in 1946 in Srinagar to Arundati Gangoo who became well known as Mrs. Mohini Khoshoo soon afterwards.

After the partition of the Punjab State in 1947 on India's Independence, Triloki Nath Khoshoo joined Panjab University with late Prof. PN Mehra, first as Lecturer in Pharmacognosy and then as Lecturer in the University's Botany Department located on the premises of the Khalsa College, Amrtisar. For doctoral research he again worked under the able guidance of Late Professor Mehra and was awarded Ph.D. degree in Plant Cytogenetics by Panjab University, Chandigarh in 1958. He earned very good reports from foreign examiners (Prof. CD Darlington, FRS, UK and Prof. GL Stebbins, USA).

Dr. TN Khoshoo served the Panjab University for 14 years since 1948, as Lecturer and Senior Lecturer till 1962 when he left Chandigarh and joined at Srinagar in Kashmir University as Reader & Head, Post Graduate Department of Botany. Shortly thereafter in 1964 he left Srinagar to join as Assistant Director, National Botanic Gardens (CSIR), Lucknow. After working in this capacity (1964-1974) he became Deputy Director (1974-76) and soon rose to the position of Director in 1976. It is during his stewardship of the National Botanic Gardens that the name of the institution was changed to National Botanical Research Institute (NBRI) in 1978. Soon after, he was elected Fellow of the Indian National Science Academy in recognition of his outstanding researches in Plant Cytogenetics. It is under his leadership that the NBRI started emerging as one of the leading institutes of the country with international recognition.

After working as Director of NBRI till 1982, Dr. Khoshoo shifted to New Delhi to join as Secretary to the Government of India, Department of Environment (DOEn), the name of which was later changed to Department of Environment and Forests. During 1982-85 Khoshoo was guiding the affairs of DOEn. It is under his guidance and directions that the basic administrative setup and functioning of this essential wing of the Government of India (GOI) was planned and established. Several environmental and forestry schemes were put in working state with very positive and far reaching results. Khoshoo was instrumental in establishing the importance of environmental planning, implementation and monitoring at national level in the fast changing scenario of degrading forestry wealth and all over rampant environmental pollution in the country. He left charge as Secretary, DOEn & Forests in 1985.

Between 1985-90 Dr. Khoshoo was working at Tata Energy Research Institute (TERI), New Delhi as Distinguished Scientist - Emeritus (CSIR) and as Consultant at TERI. For another decade, he continued his studies and research activities as environmentalist firstly as International Fellow, World Resource Institute, Washington (1991) and then as Jawaharlal Nehru Fellow (1991-93) and finally as Honorary Distinguished Fellow, (TERI) from 1993-2000. His contributions to the areas of Biomass Energy, Biodiversity, Ecodevelopment and Environmental Planning are outstanding. During the last about two years of his life, Dr. Khoshoo had serious health problems but also recovered well at times. He started coming to

TERI for few hours daily but still mentally very active and engaged himself in writing work. His office and the study room were full to the brim with books and other valuable literature, all concerning the environmental and allied areas. Finally, he eloquently interpreted views of Mahatma Gandhi in the field of human ecology and brought to the notice of public as to what Gandhi Ji stood for in relation to ecological sustainability and stability. It is only during the last four months' period of his life that Dr. Khoshoo was immobilized from active life, otherwise for over fifty year he had very active academic life. He expired on June 10, 2002 leaving behind his wife, two sons Mr. Rajiv Khoshoo and Dr. Vikram Khoshoo, and their wives and grand children greatly grieved. But, for the mother there was a great solace that both the sons are well placed in life.

Dr. TN Khoshoo was a charming personality with very sharp intellect and pleasing manners. He was quite unassuming and affectionate to his students, colleagues and friends. He was humble and polite in dealings with his subordinates. He was very popular and was counted amongst the highly learned scientists of India. He was always sought after for advice and help which he gave ungrudgingly at the cost of even personal discomfort.

CAREER RECOGNITIONS ACHIEVEMENTS AND AWARDS

Civilian Award conferred by the President of India

- Padma Bhushan (1992)

United Nations Award

- UNEP Sasakawa Environment Prize for 1996

Recognition by Scientific Academies

- Fellow, Indian National Science Academy, New Delhi
- Fellow, Indian Academy of Science, Bangalore
- Fellow, The Third World Academy of Sciences, Trieste, Italy
- Honorary Fellow, National Academy of Sciences - India, Allahabad
- Fellow, Institution of Engineers, India
- Fellow, Indian Society of Genetics and Plant Breeding, New Delhi
- Fellow, Indian Botanical Society
- Fellow, Indian Academy of Agricultural Sciences, New Delhi
- President, Botany Section, Indian Science Congress Association: 70th Session (1982)
- General President, Indian Science Congress Association: 73rd Session (1985-86)

- President, Bio-energy Society of India (1985-86)
- President, National Academy of Sciences, India (1985-86)
- President, Indian Society of Genetics and Plant Breeding (1986)
- President, Indian Society of Tree Scientists (1988-1991)
- Honorary Member, Indian Fern Society (1986-2002)

Honours and Awards

- Prince of Wales Gold Medal in Biology of Panjab University Lahore (1942) for standing first in Biology.
- Rafi Ahmad Kidwai Medal and Prize of the Indian Council of Agricultural Research, New Delhi for outstanding genetic and plant breeding work done on horticultural plants (1977).
- Birbal Sahni Gold Medal of the Indian Botanical Society for outstanding work in Plant Sciences (1982).
- Seth Memorial Medal of the Indian Society of Tree Scientists for outstanding work in forest tree genetics in particular conifers (1983).
- Ramdeo Misra Medal of the Indian Environmental Society for his valuable contribution in relation to environmental sciences (1984).
- Dayawati Vira Medal of the Agri-horticulture Society of India for outstanding work in beautifying the environment (1985).
- Sanjay Gandhi Award for the outstanding work in environment and ecology, and the services rendered to the country in these areas (1986).
- Distinguished Service Award of the Indian Science Congress 1988).
- Om Prakash Bhasin Foundation Award in Agriculture: Biomass Production, Processing and Utilization (1989).
- Distinguished Service Award of the Indian Society of Genetics and Plant Breeding (1991).
- Felicitation by Bochasanwasi Shri Aksharpurushotam Sanstha (Ahmedabad) for the "unique achievements enhancing global knowledge and outstanding contributions to the welfare of the Indian people through the field of environmental sciences" (1992).
- Indira Gandhi Environment Prize (1993), Ministry of Environment and Forests, Government of India, New Delhi for outstanding contribution in resolving environment and development issues of the country.
- Recipient of the Gandhi Medal of the UNESCO for the book: Mahatma Gandhi: An Apostle of Applied Human Ecology (1996).

- Centurial Prize (Shatabadi Puraskar) Award of Indian Science Congress (1999) for life-time contribution in the field of Environment and Sustainable Development.
- National Chairman, International Union of Biological Sciences (1981-85).
- National Chairman of the Scientific Committee on Problems of Environment (SCOPE), New Delhi (1988-91).
- Member, National Committee on International Biosphere-Geosphere Programme, Indian National Science Academy, New Delhi (1988-91).
- Member Scientific Advisory Committee, Department of Biotechnology, Government of India (1989-1996).
- Chairman Task Force on Biomass Production and Biodiversity of the Department of Biotechnology, Government of India, New Delhi (1989-92).
- Professor Pran Nath Mehra Memorial award for outstanding Research contributions in Plant Sciences (1995)

Distinguished Lecturerships

- National Lecturer of the University Grants Commission, Government of India, New Delhi (1981).
- Guru Prashad Chatterjee Lecture Award of the Indian National Science Academy, (1985).
- Dr. AC Joshi Memorial Lecture Award, Punjab University, Chandigarh (1986).
- Guru Prashad Chatterjee Lecture Award of the Indian Science Congress (1989).
- Gobind Ballab Pant Lecture Award of the GB Pant Institute of Himalayan Environment and Development (1992).
- Dr. Hussain Zaheer Memorial Lecture of the Indian Institute of Chemical Technology, Hyderabad (1992).
- Jawaharlal Nehru Birth Centenary Lecture Award of the Indian Science Congress Association: Reconciliation between Nehruvian and Gandhian Models of Development (1996).
- Dr. BP Pal Memorial Lecture Award of the National Academy of Sciences.

Very widely travelled and delivered over 200 lectures in Indian, British, French, German, Russian, Hungarian, Canadian and American Universities and research institutes and during international conferences.

Membership of Scientific Committees and Policy Making Bodies

- Deputy Chairman, Working Group on Cytogenetics, International Forestry Research Organizations, Washington (1964-67).

- Vice-Chairman, Governing Council, United Nations Environment Programme, Nairobi (1982).
- Member Scientific Advisory Committee to the Union Cabinet, Government of India (1982-85).
- Member, Indian Wildlife Board, Government of India. Chair: Prime Minister of India (1982-85).
- Member, International Task Force on Tropical Forestry, World Resources Institutes, Washington (1984).
- Member, Council of the World Resources Institutes, Washington (1988-90).
- Member, Advisory Board of the World Resources Report (1989-1998).
- Member, Plant Advisory Group of International Union for Conservation of Nature and Natural Resources, Switzerland (1988-90).
- Member, Scientific Committee of the International Lake Environment Committee, Tokyo (1988-90).
- Member, Advisory Committee on Agenda 21 to the Director General UNESCO (1993-97).
- Member, National Environmental Council of India. Chair: Prime Minister of the Government of India (1993-1995).
- Trustee, Centre for Research in Environment, Ecology and Development (CREED, 1995-2002).
- Trustee, World Wide Fund for Nature, New Delhi, India (1996-2002).

Editorial Assignments

- Former Co-Editor, Silvae Genetica, International Journal of Forest Genetics and Tree Breeding, Germany (1960-84).
- Member, Editorial Board, Plant Systematics and Evolution. Springer Verlag, Vienna and New York (1978-93).
- Member, Advisory Board, Lakes and Reservoirs: Research and Management, International Lake Environment Committee Foundation, Shiga, Japan (1994-).
- Member, Editorial Board on Environment, Development and Sustainability. Kluwer Academic Publishers, The Netherlands (1998-2002).

Publications

- Author of 9 and editor of 11 books on botanical research and sustainable management of geosphere, biosphere, natural resources and environment.
- Author of more than 235 research papers published in journals of international repute dealing with cytogenetics as related to plant evolution and breeding, biomass energy, forestry, biodiversity (conservation and utilization) and

management of natural resources and environment. He has a very high citation index.

- Authored 27 popular articles in newspaper on topical issues in environment and development.

R & D and other Achievements

Appreciation by the Government of India

The Indira Gandhi Paryavaran (Environment Puraskar Prize) for 1993 (Individual Category) was awarded to Dr. Khoshoo "in recognition of his wide ranging and incisive contributions to the field of environmental management and sustainable development":

> *"Dr. TN Khoshoo's breadth of vision and depth of knowledge, coupled with his broad humanism has made him what he is today, a dedicated strategist for human survival. His work both in high office and outside relating to management of resources, the utilization of biodiversity and the need to develop forest for long-range ecological security, are pathbreaking."*
>
> *"The content and width of Dr. Khoshoo's understanding of issues focussing on sustainable development in the Indian context, on the ethical aspects of resource consumption, on environment friendly technology and the bio-industrial development of rural India and developing countries have contributed greatly to the integration of environmental considerations into our developmental imperatives."*

Dr. Khoshoo has authored several research papers/books in the field of environment and sustainable development, many of which are pioneering works of international repute.

Appreciation by Scientists

1. Commenting on Dr. Khoshoo's writings on conservation and utilization of biodiversity and inter-relationship between biodiversity, biotechnology and bioproductivity, Dr. MS Swaminathan, FRS, FNA wrote "Dr. Khoshoo combines a remarkable breath of vision and depth of knowledge coupled with these qualities his broad humanism which has led to growth of first rate scientist into dedicated strategist for human survival." Further, in his introduction to the book brought out by CSIR (GOI) in honour of Dr. Khoshoo in 1990 entitled "selected works of Dr. TN Khoshoo" Dr. Swaminathan has stated that "Dr. Khoshoo's wide-ranging and incisive contributions in the field of cytogenetics in relation to evolution and improvement are beautifully covered in this book. The depth and width of Dr. Khoshoo's understanding of issues on cytogenetics will be clear from the different papers included in this volume. His

contributions to conservation of biodiversity have been significant. I am confident that this book will stimulate students and scholars of genetics, cytogentics and breeding to undertake research which would help to add the dimension of ecological sustainability to the goals of improving productivity and profitability".

2. In his introduction to Dr. Khoshoo's book entitled "Ecodevelopment of Alkaline Land" Prof. MGK Menon, FRS, FNA considers the work of a "path-finding" type. Through concerted efforts made by Dr. Khoshoo and team of scientists of NBRI led by Late Dr. PD Dogra, the barren wasteland of Banthera which was at one time devoid of any vegetation has been transformed into a green area through community action involving local people resulting in environmental, social and economic rehabilitation of the area as a whole.
3. Expressing his opinion about the experimental analysis of variation and evolution in *Sisymbrium irio* complex Prof. GL Stebbins (USA) has described the work "as most excellent piece of work, truly exceptional in originality, initiative thoroughness of execution and entirely accurate. This work has been quoted in many books on the subject one of these (Genetics and Twentieth Century Darwinism, 'Cold Spring Harbor' Symposium on Quantitative Biology (1959) refers to it "as most elegant piece of work".

Other Achievements

Dr. Khoshoo has made significant contributions to the genetic-evolutionary understanding of several non-agricultural economic plants (including ornamentals). He applied this knowledge for their improvement and has evolved over 30 cultivars of ornamentals, many of which are in nursery trade thus helping in beautifying the environment. He also made original contributions towards elucidating the genetic system of gymnosperms (softwoods in particular). Many of the basic concepts developed by him are known for their originality and have stood the test of the time. This work has considerable practical implications for tree breeding and genetics, and is aimed at making forestry in India and also in developing countries sustainable, and help in long-range ecological security.

From 1980 onwards, Dr. Khoshoo turned his attention to R & D regarding biomass production on degraded lands, a work that has considerable socio-economic implications at the grassroots. This work has led to ecological revival of derelict lands with a new state of human-made biodiversity in natural locations. The knowledge thus gained has been useful in ushering several ecodevelopmental programmes. It was also the basis of his starting world's first Ecotask Force involving Army for ecodevelopment of Mussoorie Hills.

He was also involved in paraphrasing sustainable development in the Indian context, and has spear-headed science and technology-based environmentalism. He

has written extensively on these topics. He is the principal architect of some major environmental initiatives taken up in the country, e.g. the Ganga Action Plan, Institutes of Himalayan Environment and Development, Centres of Excellence in Environment, Ecodevelopment of degraded lands, Conservation and utilization of biodiversity on a holistic basis, etc. He has been responsible in modulating the thinking on environment and development issues not only in India but also in the Asian Region and the developing countries at large.

Dr. Khoshoo has written extensively on the relationship between biodiversity, bioproductivity and technology (genetics, breeding biotechnology, pharmaceutical sciences) taking into account the strengths and weaknesses of developing countries in general and India in particular. He also suggested the path that India should follow so as to reap the benefit of its rich biodiversity. These ideas have been received all over the world with great appreciation, because these lead to a credible and implementable policy for conservation and utilization of biodiversity in developing countries.

Dr. Khoshoo has written, broadcast (over television and radio) and lectured extensively on various aspects of environment and development issues. Such popular articles have appeared in all the important dailies of India. These have played a significant role in building awareness, shaping current thought and government policies in India particularly on issues regarding environment, development, and biodiversity. He has also conceived and organised several science and technology-based exhibitions on environment and development issues, herbal drugs and non-agricultural economic plants, commercial floriculture, etc.

Till the end of his life, Late Dr. Khoshoo was involved in the study of the state of environment and development in the equatorial/tropical/subtropical belt in which most developing countries are located. These countries are rich in solar capital, earth capital and human capital, yet these are poor. The root cause is lack of technology utilization regarding the three capitals for the good, the benefit and the well being of people of this belt.

Monographs on Mahatma Gandhi's Environmentalism

Two monographs were published on the subject. The first one was entitled "Mahatma Gandhi: An apostle of applied human ecology" (TERI, 1995) published during the 125th birth year of Gandhiji. This was followed by another one in 1996 entitled "Gandhi and the Environment" (WWF-India). For the first time Gandhiji's perceptions on environment and development were recorded. His messages are indeed timeless and show the importance of bottom-up development for the developing countries. It highlights an urgent need for a creative synthesis between top-down and bottom-up approaches in development for the good, the benefit and the well being of the people in India and the developing world at large. This work

has been regarded as "pathfinding". These books are such that "one can open at any page and find inspiration" and are "of immense intellectual interest", and have been received very well throughout the world.

Building a Cadre of Associates in Environment and Development

With the cooperation and help of Tata Energy Research Institute, Dr. Khoshoo, as the Honorary National Programme Director of the Rockefeller Foundation-sponsored LEAD (Leadership in Environment and Development) Programme, has been responsible for organizing a first-rate training course on environment and development issues for LEAD Associates. The Associates were drawn from the Indian Administrative Service personnel employed in the States and from the Union Government establishments, public sector industrial undertakings, private industry, academic institutions and non-government organizations. The Associates thus trained have been adjudged among the best by the International Steering Committee of the LEAD Institute. There is today a very large LEAD fraternity in over 10 developing countries in the world.

RESEARCH AND DEVELOPMENT WORK*

Khoshoo's research career can be divided into six overlapping phases, coinciding more or less with the positions he held in life as (i) Lecturer, and Senior Lecturer at Panjab University, (ii) Reader & Head of the Department at Kashmir University, (iii) Assistant Director and Deputy Director, National Botanical Research Institute (NBRI), (iv) Director, NBRI, (v) Secretary, Department of Environment & Forests, Government of India, and (vi) Distinguished Scientist (CSIR) and subsequently at Tata Energy Research Institute, New Delhi in various positions.

Dr. Khoshoo's predominant research interests have been the enrichment of environment through his experimental evolutionary studies on weeds, and cytogenetics as related to plant evolution and improvement of forest trees (as input in forest tree conservation and breeding), subsidiary food plants (for subsistence agriculture) and ornamentals (for beautifying the environment). Finally his interests shifted to plants in relation to environment: energy and resource management, biodiversity, evaluation and conservation and environmental policy making.

A brief account of the research work published either independently or in collaboration with scientists (which included his teacher, students and younger colleagues) is given hereafter. It will be of interest to mention that numerous findings of Khoshoo and his collaborators have been cited in research and text books.

* Partly based on write-up by Late Dr. Khoshoo.

1. Cytogenetics of Trees (1948-55)

During this period, Khoshoo concentrated on the cytology and cytogenetic aspects of conifers, the softwood timber trees (see *J Genet.* **54:** 165-185, 1956). Later on, he widened the scope of this work so as to cover the entire group of gymnosperms.

On the whole, his studies revealed amply that much of the evolution in this group of woody plants has been through gene mutations, hybridization and karyotypic changes, apomixis and polyploidy having played little or no role. Khoshoo (1964) emphasized that the phenomena promoting genetic constancy like apomixis are incompatible with the genetic evolutionary needs of a group like Gymnosperms in which individuals are long lived and slow growing perennials. Such a genetic pattern has some taxonomic and evolutionary implications which have been discussed by him in depth. However, the importance of this pattern in planning sound improvement programmes of these forest trees is apparent. For instance, better results are expected after hybridization followed by selection rather than polyploidy. The latter may be of use at the triploid level, and in this connection it is of interest to note that triploid *Larix* raised after interspecific hybridization has vigorous growth.

In a series of analytical papers, he was able to unravel the genetic architecture of gymnosperms as a whole. He advanced new hypotheses to explain the different traits of the genetic system, as also the different mechanisms underlying the evolutionary diversification in the group. In 1957, Khoshoo observed that some tress of *Cephalotaxus drupacea* var. *pedunculata* at Dehra Dun showed the presence of 12 bivalents in the spore mother cells (PMCs) at prometaphase and metaphase I (Figure 1a) during meiosis as had earlier been reported by Mehra and Khoshoo (1956). The resultant pollen were apparently normal. However, in other trees only about 5% PMCs showed normal meiosis while in the remaining 95% PMCs the bivalents become highly contracted, terminalized and irregularly distributed (Figures 1b, c) due to the lack of directive influence of the spindle in the cells. The IIs were scattered in PMCs in different groups and anaphase II showed 48 chromatids (Figure 1d). Due to irregularities at different stages of meiotic division the result was the formation of irregular-sized pollen. The polyads had different number of microspores (Figure 1e). Khoshoo suggested that the meiotic irregularities were due to the non-functioning of the spindle and were not due to the environmental cause since the good pollen and bad pollen bearing trees grew side by side. These irregularities are due to genic change which of course, is not dominant or specific.

He discovered, for the first time in the plant kingdom, a unique all-telocentric karyotype (Figures 2a-c) in the bizarre monotypic genus of gymnosperms, *Welwitschia mirabilis* (Khoshoo & Ahuja, 1962). Elaborating on 'Chromosome Evolution in Cycads' Khoshoo (1969) pointed out that (i) the living cycads have four basic numbers: 8 (*Zamia, Ceratozamia, Stangeria*), 9 (*Bowenia, Macrozamia, Lepidozamia*

Dioon, Encephalartos), 11 (*Cycas*), and 13 (*Microcycas*), (ii) from comparison of karyotypic and morphological characters it is apparent that *Zamia* is primitive with low chromosome number and symmetrical karyotype while *Cycas* is advanced with high chromosome number and asymmetrical karotype, and (iii) there is a general increase in the number and asymmetry in the karyotypes which runs more or less parallel to the morphological evolution of the group (Figure 3).

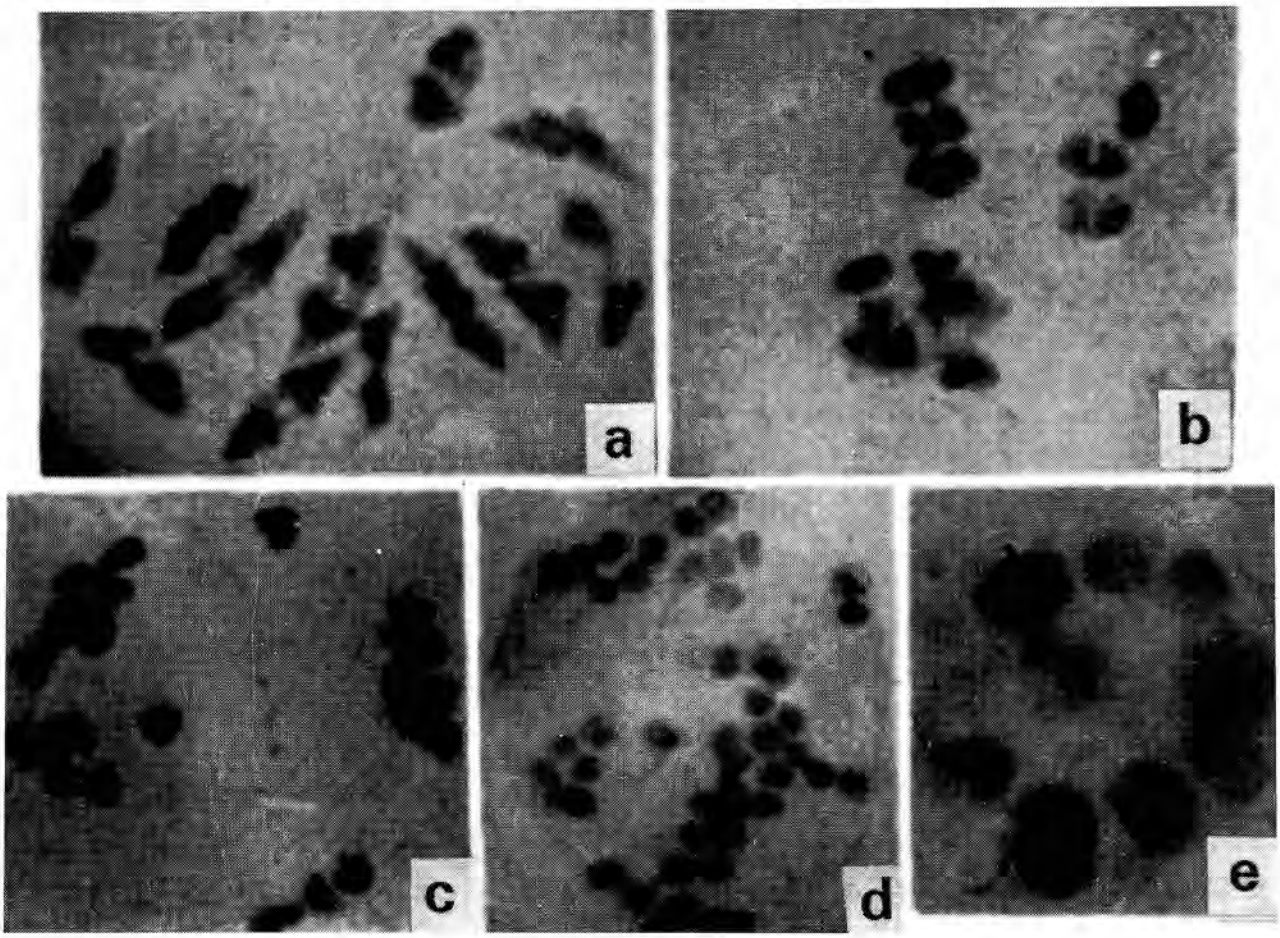

Fig. 1: Cephalotaxus drupacea var. pedunculata (cf. Khoshoo 1957) a, Twelve bivalents at metaphase I; b, Abnormal metaphase I showing contracted and terminalised bivalents which are distributed in three groups; c, Anaphase I showing 24 univalents distributed in 6 groups; d, Anaphase II showing 48 chromatids which are irregularly distributed; e, A polyad containing 10 microspores, one of which is out of focus. All approx., x 1500.

His work has been of considerable practical importance in forest tree breeding programmes for chalking out breeding methodologies for this economically and environmentally important group of plants. The basic idea has been to confer on these tree species both immediate fitness and long-term genetic flexibility. In essence, the objective should be to maintain a high degree of genetic diversity in forest tree populations. Thereby simulating organic evolution, and ensuring survival under changing environmental conditions.

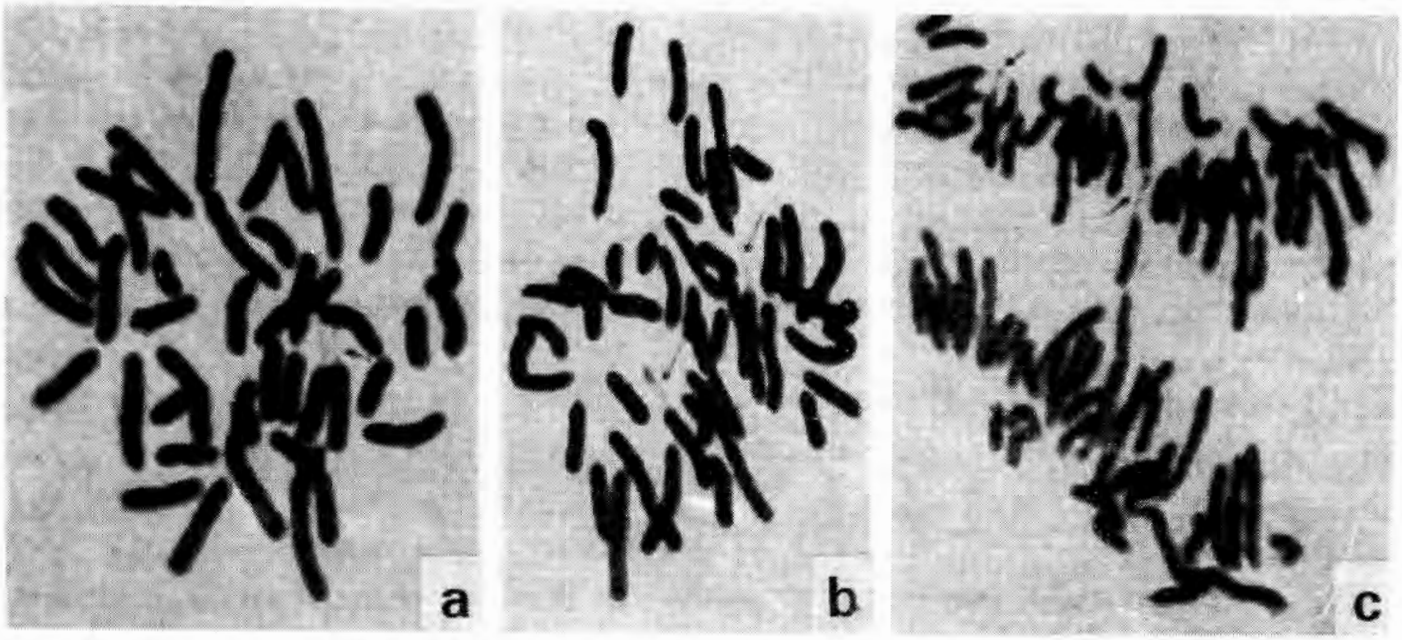

Fig. 2: Welwitschia mirabalis (cf. Khoshoo 1962) a-b, Metaphase in root tip cells showing 42 telocentric chromosomes. Only two chromosomes are satellited (a, x c.1600; b, x c.1250) c, Anaphase showing the telocentric nature of the centromeres. The chromosomes are more or less straight and parallel to the spindle axis. The orientation of the sat-chromosomes is identical with other chromosomes of the complement (x c.1350).

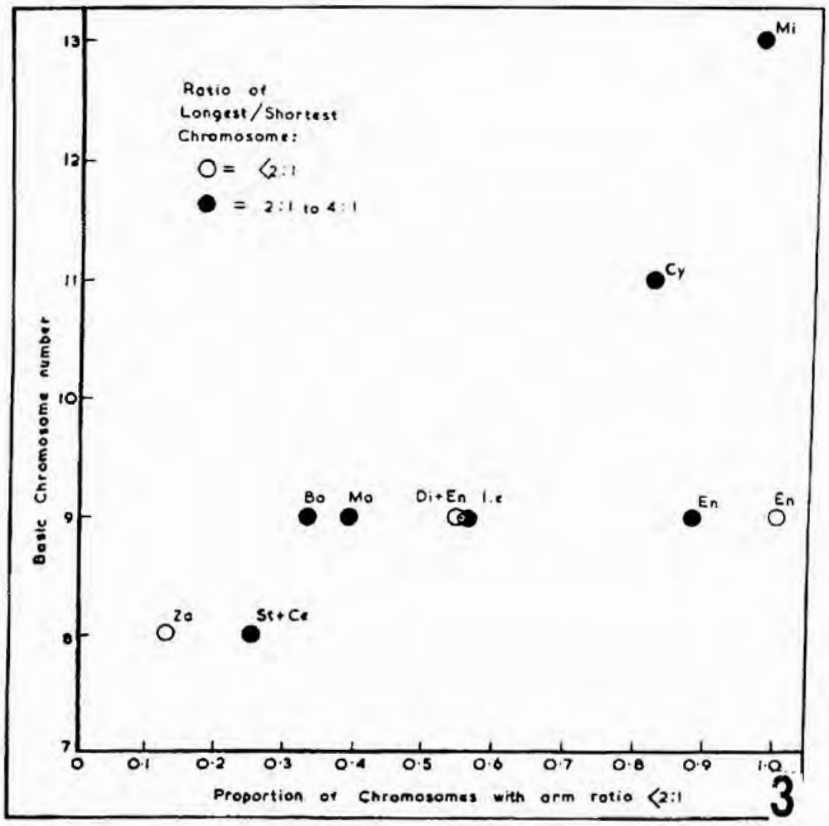

Fig. 3: Correlation of karotypic asymmetry and basic number in cycads. Bo = Bowenia, Ce = Ceratozamia, Cy = Cycas, Di = Dioon, En = Encephalortos, Le = Lepidozamia, Ma = Macrozamia, Mi=Microcycas, St = Stangeria and Za = Zamia (cf. Khoshoo 1969).

Khoshoo had turned his attention to the evolutionary implications of the variation in DNA content in chromosomes of gymnospermous taxa and other trees, and had related these data to their habitat and other aspects of environment. Before his sad demise, he had been engaged, in collaboration with Dr. D Ohri (NBRI), in the preparation of a comprehensive review on Cytological Evolution of Gymnosperms taking also into account their geographical distribution and morphological diversification. Hopefully, the monograph would be published in the near future.

2. Experimental Evolutionary Studies (1955-64)

During this period, Khoshoo worked on experimental evolution in polymorphic weeds, vegetables, minor fruits and medicinal plants. He studied in detail the evolutionary dynamics involving analysis of breeding systems, cytogenetics, eco-geography and competitive ability. Based on the data emanating from these studies, the variation patterns were recorded in traditional taxonomic units so as to reflect evolutionary relationships as accurately as possible. His work on the experimental analysis of variation and evolution within *Sisymbrium irio* complex published in a series of papers, is of special significance. This complex is an intricate mixture of diploid to octoploid races with rampant allo- and auto-alloploidy. He was able to synthesize experimentally natural polyploidy types.

Explaining the distribution patterns of various cytotypes in *Sisymbrium irio* complex Khoshoo (1966) pointed out that the diploid race is northern in distribution. Its wide distribution suggests that it is not a recent taxon and is undergoing active evolution. Hexaploid is reported primarily from Punjab (India and Pakistan) wherever diploid and tetraploid races come in contact. The octoploid is strictly very recent and is a stray taxon. The wide distribution of *Sisymbrium irio* complex as a whole is due to its genetic system which meets the requirements of a perfect weed (Figure 4).

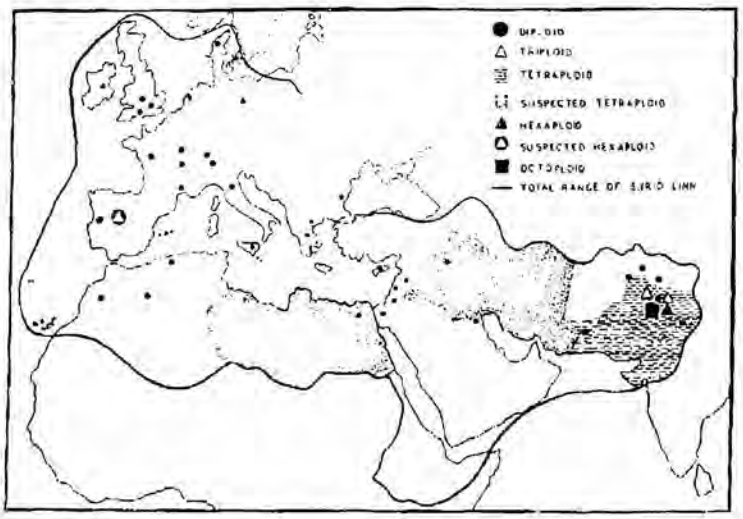

Fig. 4: Map depicts the present state of knowledge about the distributional pattern of Sisymbrium irio complex (cf. Khoshoo 1966)

Fruit Plants: Jujube is one of the most common wild fruit trees in India of which a number of superior types are now in regular cultivation. It is a complex of tetra-, penta-, hexa- and octoploid cultivars. Among these, the tetraploid, varieties have higher fruit weight and higher percentage of pulp and sugar and lower citric acid content besides being prolific yielders. One seedless octoploid, though with lower fruit weight, has most of the fruit as pulp and contains the highest percentage of sugar (21.4%). The taxonomic difficulties stem from the polymorphicity created by entomophily, hybridization and segmental alloploidy. These types throw segregates which connect the parents.

In India, jujubes range predominantly from 4x to 8x, and 2x varieties are not found. Any discussion on the place of origin of this fruit (India and/or China) must wait till such time the situation in Chinese jujubes is known.

Vegetables: "Tinda" is the common summer fruit vegetable in north western India and has been considered a variety (var. *fistulosus*) of watermelon (*Citrullus vulgaris*). However, experimental evolutionary investigation has shown that "Tinda" is hardly related to watermelon but is a distinct taxon (*Praecitrulus fistulosus*) both on morphological and cytogenetical considerations. While the native home of watermelon (n=11) is tropical Africa, "Tinda" (n=12) is endemic to north western India.

Purslane (*Portulaca oleracea*) is an important pot-herb in India and in its cultivated form has large plant type with bigger obtriangular leaves. This type has arisen as a mutation of larger size from the wild weedy type with obovate leaves.

Medicinal Plants: In this group, special attention has been paid to *Artemesia* (source of anthelmenthic drug santonin), colocynth (*Citrullus colocynthis*) used for colocynthin, large garlic (*Allium ampeloprasum*) preferentially used for its expectorant properties, Chirata (*Swertia* species), an indigenous bitter tonic drug, and colchicine-containing plants (*Colchicum* and *Merrendera*). Special attention has been paid to the analysis of their cytogenetic patterns and geographical distribution.

3. Evolution and Improvement of Non-Agricultural Economic Plants (1964-76)

This period marks the important phase of experimental analysis of variation under both natural and domesticated conditions, also synthesis of new and improved cultivars of non-agricultural economic plants, particularly ornamental and subsidiary food plants. Khoshoo was able to manipulate purposefully, genes, chromosomes and genomes for increased novelty and/or productivity of some ornamental and subsidiary food plants. Since plant breeding is essentially plant evolution under the direction of man, this phase of Khoshoo's work is a continuation of his earlier experimental-evolutionary and biosystematical studies of weeds of

cultivation (e.g. *Sisymbrium*). Thus the objectives of his work were both basic and creative (experimental analysis of the cause of variation and evolution) and applied and productive (experimental synthesis of new and novel variation with better putative parents). Considering the fact that all over the world, improvement of ornamentals is essentially nurseryman's trade secret, Khoshoo's aim was to build indigenous know-how in this area. Through this work, he has generated considerable new knowledge, and good basic information has been unravelled regarding the genetic-evolutionary race history of a number of such plants. Using cytogenetic techniques, he has worked out the genetic mechanisms underlying the transformation of small flowered wild types, into large flowered cultivated types during the process of domestication of ornamental and subsidiary food plants. Based on this knowledge, he also delineated, for the first time, centres of their diversity/ origin, circumscribed gene pools and standardized procedures for studying the taxonomy of cultivated plants (Horticultural Taxonomy). Some of the cultivars synthesized and released in *Bougainvilleas, Amaranths,* gladiolus and *Chrysanthemum* have been regarded as unique and have gone in nursery trade.

In brief, his major achievements in this area have been perfecting the breeding methodology for F_1 hybrid, seed production of triploid marigolds and free flowering colourful hybrid verbenas as ground cover; new tropicalized cultivars in amaranths, bougainvilleas, chrysanthemums, and gladiolus; tetra-giant snapdragons; transfer of resistance to grain amaranths from wild relatives for major pest (*Hypolixus trunculatus*), etc. This work earned him a place in ornamental horticulture for its high scientific quality on the one hand and for enhancing the beauty of environment and evolution of tropicalized cultivars on the other.

Thanks to the outstanding cytogentic and biochemical work done by him and his team on protein rich grain-amaranths with their carotene-rich leaves, today these crops, on account of their being of short duration, hardy and less demanding, are high priority new crops of the world, particularly as a source of weaning food for mitigating protein malnutrition in the developing world.

3.1 Genetic-Evolutionary Race Histories of some Ornamental Plants

Unlike crop plants, the genetic events involved in the origin and evolution of many non-crop cultivated plants are not well worked out. Knowledge of such genetic evolutionary race histories is of considerable importance because they reveal the course a wild plant followed during domestication and its transformation into cultivated condition. As in crop plants such knowledge not only helps in reconstruction of a cultivated plant from its putative parents using better lines and having desired characteristics, but it also helps in generating new variability. Furthermore, such studies have also led to an understanding of the principles involved in their selection together with the limits of gene pool to be utilized for their improvement and future aims of breeding and standardizing plant breeding

methods. With this aim, such knowledge has been built up meticulously by Khoshoo and his collaborators through chromosomal analysis followed by, as far as possible, synthesis of the cultivated taxa in *Alliums, Amaranthus, Amaryllis* (Fig. 5), *Antirrhinum, Bougainvillea* (Figure 6), *Canna* (Figures 7 and 8), *Celosia, Cockscomb, Costus, Crinum, Eragrostis, Gloriosa, Hedichium, Hemenocallis, Hibiscus, Lagerstroemia, Lantana* (Figure 9), *Pansy, Petunia, Portulaca, Ruellia,* snapdragon, *Tagetes, Verbena, Viola* and *Zephyranthes*. Salient features of these studies are detailed by Khoshoo (1979).

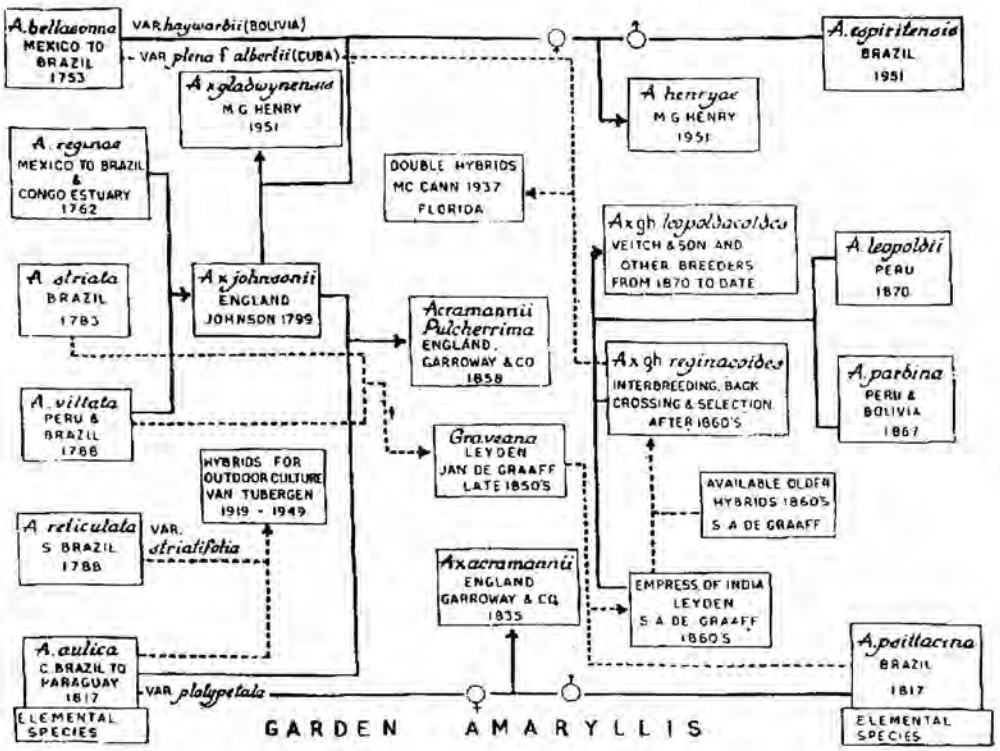

Fig. 5: Origin of garden Amaryllis is depicted (cf. Narain and Khoshoo 1977)

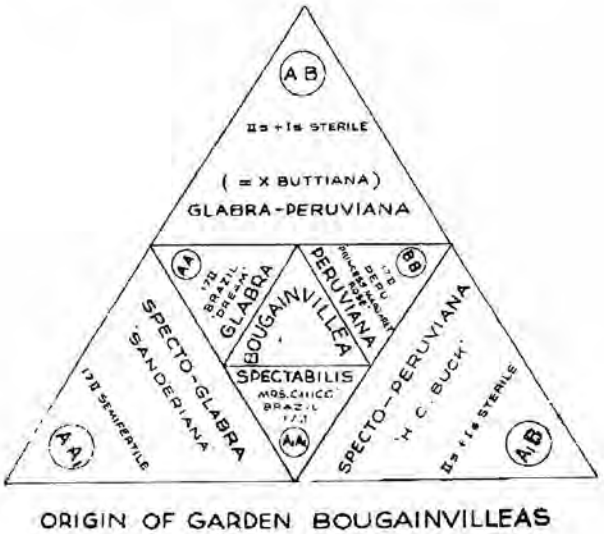

Fig. 6: Origin of chief groups of cultivated Bougainvilleas together with elemental species (cf. Khoshoo 197

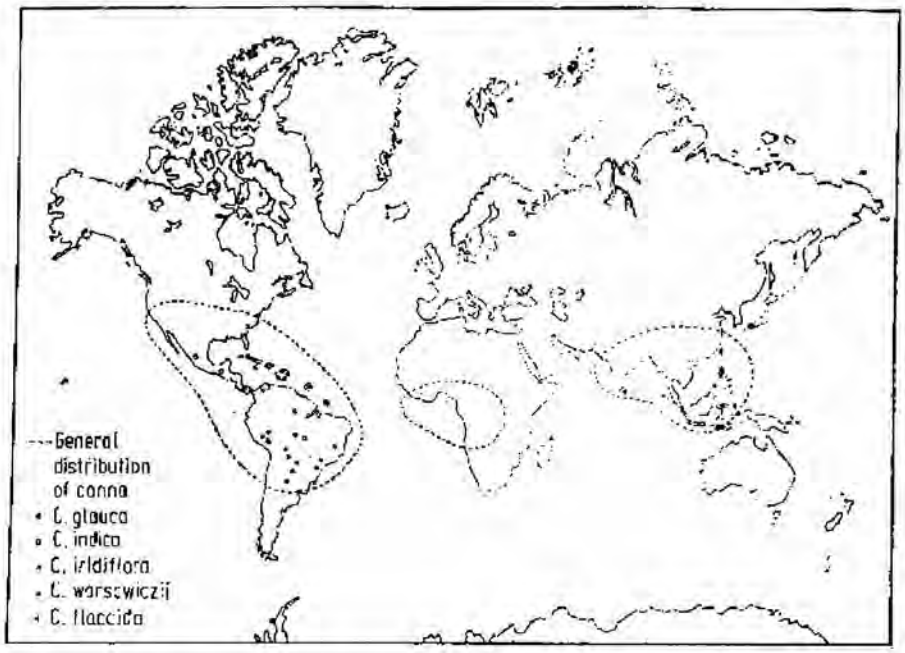

Fig. 7: Map showing the distribution of the five elemental species together with the overall distribution of the genus Canna (cf. Khoshoo and Mukherjee 1970)

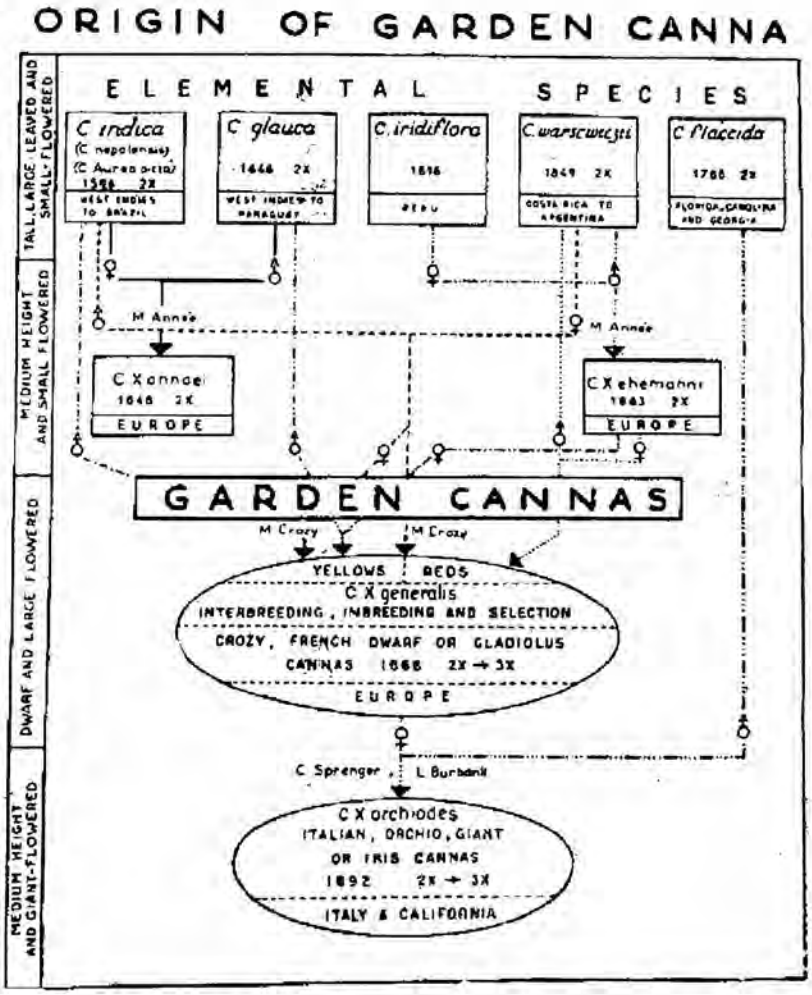

Fig. 8: Depicts the origin of the chief two groups of garden Cannas along with their characters like plant height and size of flower (cf. Khoshoo and Mukherjee 1970)

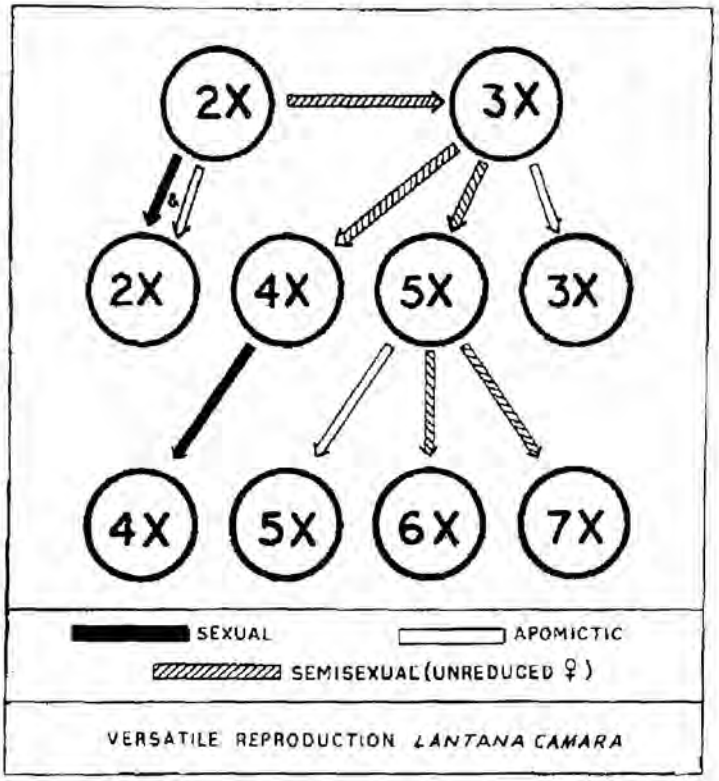

Fig. 9: Versatile reproduction in Lantana camara which varies from truely sexual through semi-sexual to obligate apomixis. Thus a diploid can in course of time generate variability at polyploid level. The versatility in reproduction aided by stabilized polyploid forms; vegetative propagation and seed dispersal by birds, have all helped in the production of numerous existing forms which have created taxonomic enigma (cf. Khoshoo and Mahal 1967).

3.2 Applied-Basic Studies

As a prelude to some of the foregoing applied work, necessary applied-basic studies had to be made. Some of these are of considerable interest to practical plant breeding and these are: control over male fertility; reproductively versatility method for improving ornamental lantanas and zephryanthes lilies; poly-aneuploid system in garden *Zephyranthes* and *Hibiscus*; sudden change in breeding system (from chasmogamy to cleistogamy) in ornamental ruellias following hybridization; genetic isolation of the different genomes in polyploid garden clump verbena and cockscomb; development of trisomic lines in verbena and snapdragon; subhaploid pollen grains; genetics of bivalent pairing in hexaploid species of *Verbena*, genetic tumours and virus-like and other syndromes in hybrid amaranths as barriers to free manipulation of genes; cytogenetic patterns in amaranths cultivated for grain and as pot herbs and ornamentals; all-telocentric karyotype in *Welwitschia mirabilis*, etc. These findings are highly significant and have been referred to in the text books and research communications.

3.3 Production of Hybrid and Polyploid Ornamentals

By cultivating in different seasons and in different parts of India, ornamental plants can be grown for home use and export all the year round. Therefore, India with its rich ecogeography and wild ornamental plant wealth is one of the best countries to pursue such work. Attempts have also been made to develop basic know-how for raising F1 hybrid seed and hybrid cultivars in India, a low-wage region. Some of the significant results are:

Bougainvillea Hybrids: Progress in bougainvillea breeding has been hampered all over the world largely because of the extensive pollen and/or seed sterility. The choice of female and male parents is limited only to the few relatively fertile types which more often are not good cultivars. After detailed studies of the reasons for sterility, fertility was restored by colchiploidy. This enabled immediate broad-basing of germplasm by inclusion in breeding programme of such cultivars that were otherwise very useful but so far out of reach for bougainvillea breeders all over the world. Following the work done at NBRI by Khoshoo and collaborators, there are now seeded counterparts of several sterile but very popular varieties. These have been used to raise a number of very promising, colourful and floriferous, often bicoloured, hybrid varieties at triploid and aneuploid levels. Some of these are ideal for pot culture. Special mention may be made of "Begum Sikander", "Wajid Ali Shah", "Mary Palmer Special", and others with blotched bracts.

Free-Flowering Hybrid Verbenas: Four cultivars have been evolved by hybridizing hard but less colourful, small-flowered species *V.tenuisecta* which grows almost throughout the year and is used as ground cover and *V.hybrida*, an annual, highly showy, large-flowered bedding species. The hybrid types obtained after repeated back crossing are summer-hardy, with genes that confer heat resistance, matting habit, and with reasonably large but highly showy flowers. The hybrids have genic male sterility and normally do not set seed which makes them highly floriferous and free-flowering. It has been possible to extend the blooming period because of male sterility. These verbenas are excellent both as ground cover for rockeries and as bedding types. The hybrids can be propagated vegetatively.

Hybrid Amaranths Ornamental: This is totally new ornamental plant with very appealing maroon coloured beaded erect inflorescence selected from a segregating progeny in a cross within *Amaranthus caudatus* complex and has given a perfectly uniform progeny.

Foliage Amaranths: These are indigenous to India and apart from their uses as pot herbs, over the years they have been selected for their colourful foliage. Five new cultivars have been developed, two of which are unique. Out of these, one has green foliage in the lower part, while the top is crowned with golden yellow leaves. The other is an auto-tetraploid which, besides being hardier, has deeper coloured,

broader foliage than its diploids. All the five cultivars are true breeding and uniform and make the garden colourful during "lean" summer months when there are hardly any ornamentals in bloom.

F1 Hybrid Triploid Marigolds: Marigold is one of the most important flowers of India being used both for religious and decorative purposes. Complete technology [including maintenance of male sterile (ms) line] through the use of ms African diploid marigolds (*Tagetes erecta*) and fertile French tetraploid marigold (T. *patula*) has been worked out and stepped up to commercial scale. The F1 hybrids are dwarf, highly floriferous and free flowering (due to sterility) with uniform golden yellow heads giving nearly 1.5 times more flowers by weight per unit area.

Gloriosa Hybrids: The beautiful glory lilies have an excellent future as cut flowers exhibiting a delightful change in colour during blooming and are available in rainy season when there is general paucity of flowers. Selection amongst the progeny of hybrids has yielded a number of hybrids. The specific objectives of selection are lengthening of flowering period and increasing colour diversity, size and keeping qualities of the flowers. With the increase in ploidy level there is increase in diameter, breadth of perianth, intensification of colour and keeping qualities of flowers.

Amaryllis Hybrids: The most common cultivars of this important cut flower are diploids and some are tetraploids. In order to combine the heterotic effect of hybridization and gigantism associated with polyploidy, a number of triploid hybrids were raised. These have given consistently excellent performance because of higher number of larger, ruffled, intensely coloured and longer lasting flowers per spike.

F1 Hybrid Floral-Cluster Snapdragons: These involve inbred lines of the conventional snapdragons (*Antirrhinum majus*) selected on the basis of their height, compactness of inflorescence, number of flowering stems per plant, blooming period, number of flowers open at a time, number of flowers per inflorescence, size, colour and duration of flowers and fertility. These lines were pollinated with a very dwarf species (*A. glutinosum*). The resultant F1 hybrids are uniform with semi-dwarf habit and large number of tillers with prominently held inflorescence bearing closely set reasonably large flowers. A very valuable character is their perfectly synchronous flowering not only in each flowering shoot (a florist's dream), but also between tillers of a plant and there is even interplant synchrony.

Tetra-Giant Snapdragons and other Ornamentals: These were raised from some F1 hybrids giving good performance under Indian conditions. The tetra-snaps have undergone selection for 5 generations. The resultant tetraploids are hardier, sturdier, stockier and shorter than the corresponding diploids. They have generally a higher number of flowering stems with conspicuously larger, deeper coloured flowers that

are longer lasting than their diploid counterparts. Fertility is about 80-90% of the normal diploids. A very important attribute of tetra-snapdragons is the very strong "triploid barrier" (0.24% triploid after 4x X 2x crosses) and thus the diploid and tetraploid types can be grown together. This property, together with other useful attributes enable raising commercially exploitable, fertile, true breeding and vigorous tropicalized tetra-snapdragons in different colours. This technique is being followed in other flower and foliage ornamentals like amaranths.

3.4 Genetics and Breeding of some Food Plants

Protein and Carotene-rich Amaranths: Grain and vegetable amaranths with their high calorific value and protein, vitamin A and iron contents respectively can play a very important role in any "Protein-Vitamin H-Iron" Nutrition Plan. Furthermore, the amino acid composition of their proteins in their unimproved state compares favourably with some improved cereals. Besides, amaranths can grow in areas and climates ordinarily inhospitable to the major cereals.

After detailed applied-basic studies, which were totally lacking so far, it has been possible to transfer resistance to major amaranths pest (*Hypolixus trunculatus*) from the wild source (*Amaranths hybridus*) to the most widely cultivated amaranths (*A. hypochondriacus*). Besides manipulating this important character, it has been possible to transfer other characters such as hardiness and adapatability to inferior soils. Such hybrid segregates have been back crossed to the cultivated parent to make them high yielding.

In the grain Amaranthus group, four also domesticated species (*A. hypochondriacus* Linn., *A. cruentus* Linn., *A. caudatus* Linn., *A. caudatus* var. *atropurpureus* Hort. and *A. adulis* Spegazrini, one ancestral weedy species (*A. hybridus* Linn.) and eight hybrids, namely *A. edulis* × *A. hypochondriacus*, *A. edulis* × *A. caudatus*, *A. edulis* × *A. caudatus* var. *atropurpureus*, *A. caudatus* × *A. hybridus*, *A. caudatus* × *A. hypochondriacus*, *A. edulis* × *A. hybridus*, *A. hybridus* × *A. hypochondriacus* and *A. edulis* × *A. cruentus* were studied by Khoshoo and Pal, (1970) and Pal and Khoshoo (1973a). The results as presented by Khoshoo (1979) are shown in Figure 10.

The autotetraploid grain amaranths were rigorously selected for over seven years. They have maintained some useful characters such as non-lodging, sturdy and dwarfish plant type with 80-90% fertility, 2-5 times heavier seeds and better popping and chemurgic qualities. The vegetable Amaranths such as *A. dubius*, *A. tricolor*, etc. are unparalleled because of good amount of leaf protein (4%), iron (2.55%) and vitamin A (9200-11000 i.u. per 100 grams) contents. Selections yielding high amount of green matter have been isolated together with highly productive synthetic amphiploid, *A. spino-dubius* (2n=98), which combines the useful foliar characters of *A. dubius* (2n=64) and hardy characters of the cosmopolitan weed *A. spinosus* (2n=34).

This amphiploid is very vigorous with vegetative growth almost throughout the year, besides it can grow in a number of habitats ordinarily inhospitable to *A. dubius*.

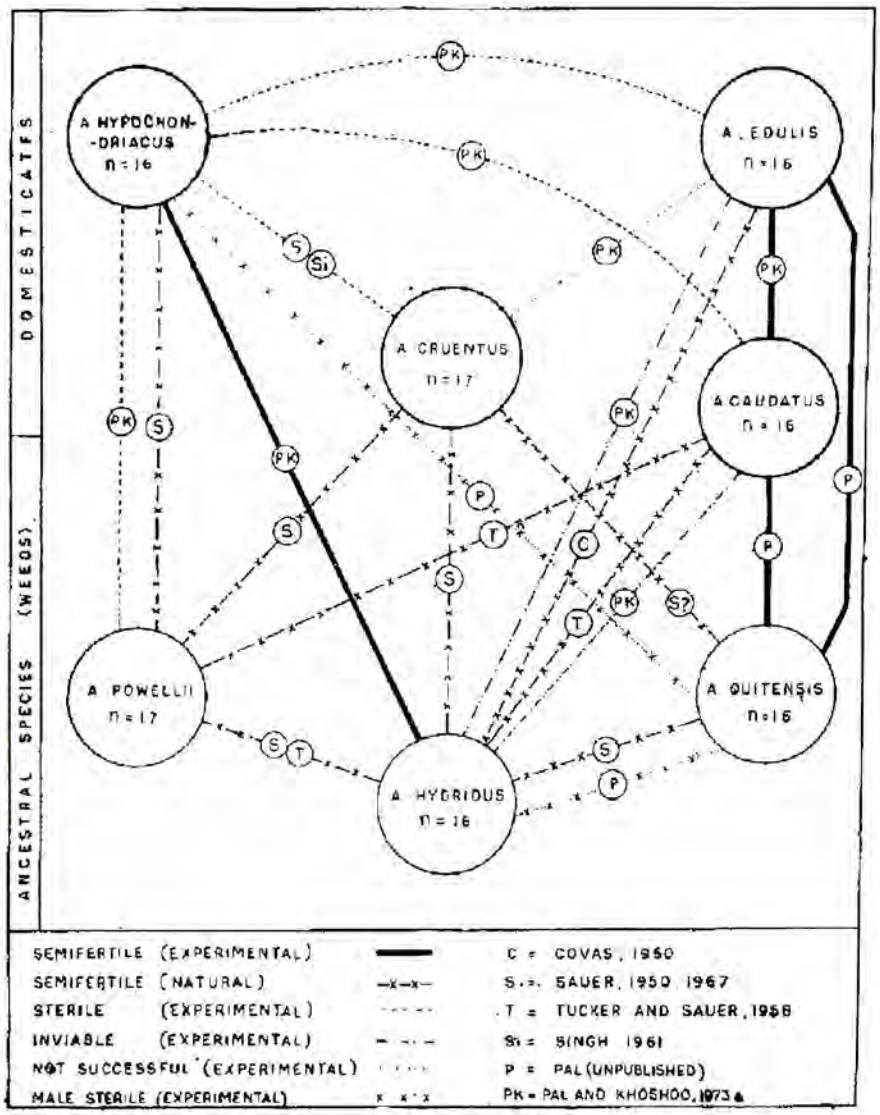

Fig. 10: Crossing polygon of 4 domesticated and 3 weed species of the grain amaranthus complex as depicted by Khoshoo (1979) [Covas G (1950), *Rev Argentina Agron* **17** 257-260; Sauer JD (1967) *Ann. Missouri Bot Gard* **54** 103-137, also see this reference for Sauer 1950; Singh HB (1961) *ICAR Cereal Crop Series* No. 1, New Delhi; Pal M and Khoshoo TN (1973) *Theort & Appl Genet* **43** 242-251; Tucker JM and Sauer JD (1958) *Madrono* **14** 232-261]

3.5 Centres of Origin/Domestication of Ornamentals

The monumental work of Vavilov on the centres of origin of cultivated plants excluded ornamentals. Based on the studies done by Khoshoo's team, it has been possible to circumscribe centres of origin/domestication of the ornamentals. Since ornamentals have been more mobile than crop plants, the centres of domestication of cultigens are more often different from the centres of diversity and the ancestral species. The former tally more or less with those delineated by Vavilov for crop

plants. With regard to their origin, different ornamentals have been classified depending upon the number of species (one or more) involved in the origin and the nature of genetic mechanisms underlying their evolution. Furthermore, an understanding of the origin and evolution has been helpful in bringing out the limits of the gene pools to be utilized for future improvement.

3.6 Hortorium Taxonomy or the Taxonomy of Cultivated Plants

So far this has been a totally neglected subject. Due to domestication, there is a greater speed of morphological evolution in cultivated plants in comparison to the wild plants, and the commensurate genetic differentiation lags behind. Thus morphologically they may transgress the taxonomic limits of not only the species but even the genus to which they belong. However, they are genetically more often still nonspecific. Therefore, the concept of morphological distinctness which is an important prerequisite of the utilitarian taxonomy of the wild plants, cannot be applied uncritically to cultivated plants. The problem was considered from different aspects, and a workable taxonomic system of cultivated plants has been evolved. Such a system must begin with the ancestral species classified under Botanical Code followed by cultivated species in which cultivars should be arranged under Cultivar Code, which does not necessarily stress botanical difference but group cultivars according to their agro-horticultural use. Each cultivar needs to be registered and typified with an authentic specimen, description, year of introduction, name exact ancestry, etc. Such accounts besides enabling recording of variation patterns, help to set future aims of breeding for creating new and meaningful variations.

Following these principles, the cultivated taxa classified are: garden canna, snapdragon, petunia, hibiscus, amaryllis, pansy, amaranths, cosmos, etc.

4. BIOMASS IN ENERGY AND ENVIRONMENT (1976-82)

Although Khoshoo continued his work on conservation of non-agricultural economic plants during this period, his main preoccupation was the restructuring of R & D work of the National Botanical Research Institute (CSIR), Lucknow. He initiated high level research programmes, especially on pollution tolerant plants for landscaping polluted areas; aerobiology of allergenic plants, man-made forests and biomass production on marginal land using high density and short rotation firewood, and alcohol, petro-plants and rubber yielding plants at the Biomass Research Centre at Lucknow. This Centre has been considered unique in so far as plant based energy systems are concerned.

One of the best examples of the restoration of degraded usar land (alkaline) can be seen at Banthra, where Khoshoo and his colleagues established the country's first Biomass Research Centre. Due to paucity of arable land, such wastelands have become relevant for meeting the escalating demands for diverse land-uses. However,

the utilization of such lands poses a major R & D challenge. The approach followed at Banthra was holistic and involved ecologically clean, low-energy as well as low-engineering inputs and utilization of human power on a voluntary basis. Essentially, the work is multisectoral in character, and is aimed at helping the small subsistence farmer through intensification and diversification of biomass production for food, fodder, fuel, fertilizer, small timber, aqua-culture, medicare, and small village level biomass-based mini-industry. A by-product of such an approach is the improvement in bio-aesthetics and micro-meterology, and the generation of wilderness areas with a mini, man-made three-storeyed forest with mammals, birds, reptiles, insects, earthworms, etc. which evolved in 20 years. Initially, different trees, shrubs and animals tolerant to usar conditions were used. In turn, these paved the way tc less tolerant species because of a perceptible amelioration in the quality of the land itself. Cultivation of many species was also cost-effective.

The transformation of such barren wasteland, devoid of any worthwhile vegetation, into a green area has been possible through community action involving local people. This brought about the environmental, social and economic rehabilitation of the area as a whole. Today, the challenge lies in converting such a micro-level success into a macro-level one.

Khoshoo also initiated work at NBRI on the standardization of herbal drugs and their compound formulations, particularly for rural use and development. The work on improvement of betelvine cultivation brought about the much needed modernization in this important but forgotten age-old rural industry, affecting the lives of millions of subsistence farmers.

The country's first integrated sewage grown *Spirulina* cultivation farm was established and its products such as biogas, fertilizer, poultry feed, fisheries and irrigation water were put to use.

Many of these projects have since spread, particularly those in the area of plants in relation to environment and rural energy. These changes in NBRI paid rich dividends and most botanical organizations have commended the dynamic approach which combines socio-economic relevance with scientific excellence. The impact of many of these programmes is apparent from the social, economic and environmental benefits that have accrued from them. In essence, the work at NBRI, under the guidance of Dr. Khoshoo (1976-82) dealt with botany in relation to environment and energy. Khoshoo's Presidential address entitled "Energy from Plants" at the Botany Section of the Indian Science Congress (1982) is regarded as important reference material as it discusses for the first time, the production, processing and utilization of biomass energy with reference to developing countries.

With Dr. Khoshoo's leadership, the restructuring of R & D plans at NBRI brought the institute into the mainstream of the CSIR and at par with its major

laboratories. This resulted in elevation in 1978 of the then National Botanic Garden (NBG) to the level of the national institute named National Botanical Research Institute which has now become the centre of R & D on underutilized non-traditional plants combining relevance with excellence.

5. ENVIRONMENTAL MANAGEMENT, PLANNING AND POLICY (1982-85)

During this period, in his capacity as Secretary to the Government of India in the Department of Environment (DOEn), Khoshoo was responsible for the formulation of policies and plans with regard to the management of environment in the country, including the work of the Botanical and Zoological Surveys, National Museum of Natural History, the Network Organization, Gobind Ballabh Pant Himalayan Institute of Environment and Development, etc. Khoshoo was also responsible for environmental management in the Indian context. His work involved scientific analysis of the environmental problems and suggesting proper remedial measures. The latter fell under two broad heads, namely: (i) Preventive or preemptive measures so as to insulate the country from future environmental damage, and (ii) Restorative or curative measures for correcting the past ecological damage. The abandoning of the Silent Valley Hydro-electric Project and a number of regulatory measures and setting of environmental standards are examples of the preventive strategy, while the Ganga Action Plan and Revegetation of Derelict Land fall under the restorative category.

The aspects covered included pollution monitoring and control, impact assessment, natural living resources conservation, eco-development, research promotion, education and training information and publication, co-ordination and liaison with states, policy and law and international co-operation. The role of basic and applied sciences, engineering, socio-economics, law and community action was also stressed. The Department of Environment was recognized as a systems builder agent of change and a catalyst. Many innovations were brought in through All India Co-ordinated Programmes on heavy metal toxicity, rural fuels, fluorosis, air pollutants and plants, biotechnology of waste management, ethnobiology, tissue culture and seed biology as a conservation strategy, biomonitoring of trace metals etc. Meaningful programmes on eco-development of watersheds and ecologically degraded areas, and environmental education, awareness and training were initiated.

In the area of pollution monitoring and control, a country wide survey of polluting industries was made together with industry-specific Minimum National Standards (MINAS) were set for eight types of industries together with guidelines and packages of practices for implementation for nationwide pollution control. All the fourteen river systems (involving 83% of the country's area, 80% of population

and 85% water discharge) were surveyed for discharge of domestic and industrial pollutants, mass-bathing, waterborne disease and establishing monitoring network of 120 stations (GEMS and MINRAS). Ganga Action Plan was evolved to clean the river system in the next 10 years. A system of tax concession for pollution control was also evolved.

Under ecodevelopment, Task Forces involving ex-servicemen were organized for ecological restoration of Rajasthan Canal Area, Shahjahanpur Block, etc. Ecodevelopment camps were organized by students, voluntary agencies and Non Government Organization (NGOs) throughout the country. Integrated Action-Oriented Projects were organized involving 14 universities in the Himalayas, 11 universities in Western Ghats and 18 universities in Ganga basin. Field Demonstration Programmes were organized in selected ecosystems, mined areas, aerial seeding, etc. In this connection, mention may be made of Dasholi Gram Samaj, Doon Valley, Pushkar Valley and Auroville Regional Development.

In the area of environmental impact assessment, questionnaires/ guidelines were evolved for projects in different sectors such as industry, power generation (hydro-electric, coal), mining, ports and harbours. Methodology was evolved for pre- and post-audit of environmental impacts of developmental projects. Environmental guidelines and follow-up action for setting up major and medium industries were evolved.

There has been a conceptual reorganization of the Botanical and the Zoological Surveys into Ecological Survey of India to take up ecological mapping of the living resources—national fauna and flora, formation of national grids of botanic gardens, herbaria, museums and zoos. Conservation of bio-diversity has been related to biosphere reserves, captive breeding and reintroduction together with *ex situ* conservation of seed biology and tissue culture of endangered species, and seed banks.

In the area of environmental education, training, awareness and curricula for teaching have been developed in co-operation with all the relevant agencies. In the non-formal area, essay and painting competitions for students; training programmes for senior executives, policy makers, administrators and planners, foundation courses for Indian Administrative and Police Services and National Defence Academy and special programmes for weaker sections of the society (villagers and women) have been undertaken together with scientific and technical manpower development. Significant achievements are:

- Centres of excellence on environmental research, training and education and mined area development were identified and supported.

- In environmental information, database have been created for water pollution, toxic chemicals, biodegradable wastes, marine biota, mining environment, renewable energy and appropriate and environmentally sound technologies.
- Under environmental policy and law, initial steps have been taken to formulate National Conservation Strategy, framework for the National Environmental Policy, revision of Water Act, and legislative and administrative measures to regulate grazing, and for pastoralism biosphere reserves, catchments and hazardous substances.

Working policies of Department of Environment, Government of India (DOEn) all through emphasized that in a developing country such as India, there is considerable dependence on renewable resources. Therefore, these together with non-renewable ones need to be managed wisely by preventing non-reversible damage to the environment. Several environmental programmes formulated by DOEn under the guidance of Dr. Khoshoo such as the Ganga Action Plan have brought together, in symbiotic partnership the scientists, technologists, ex-servicemen, governmental and non-governmental organisations, students and villagers.

6. MANAGEMENT OF RESOURCES FOR SUSTAINABLE DEVELOPMENT (1985 ONWARDS)

Lately, Khoshoo's principal interests at the R&D level were management of resources with particular reference to conservation of biological diversity, forestry for long-range ecological security and supply of goods and services to people and industry, and the utilization of derelict land for productive purposes. His interests at the policy research level were sustainable development, development of National Conservation Strategy and Environmental economies. He had generated new information and linked the same to the existing knowledge. His major contribution had been the scientific analysis of the environmental problems and evolving strategies and action plans to combat environmental damage on ground. The use of such strategies had been both preventive/pre-emptive and restorative/curative.

Some of the important works emanating during the period deal with sustainability and environmental security. As the General President of Indian Science Congress (1986), he presented his views in his Presidential Address entitled Environmental Priorities in India and Sustainable Development. For the first time he defined the sustainable development in the context of a developing country. He identified thirteen areas for priority action relevant to the particular socio-economic, cultural and ethical milieu prevailing in India which could lead to sustainable development. These areas are: Conservation ethic, Population stabilization, Integrated land use planning, Healthy cropland and grassland, Woodland and revegetation, Conservation of biological diversity, Control of pollution in water and

air, Development of non-polluting renewable energy systems, Recycling wastes and residues, Ecologically compatible human settlements and Slum improvement, Environmental education and awareness, Updating Environmental Law and New dimension to National Security.

The outcome of this analysis was that sustainability in development has to be woven into India's planning process as one of the basic and permanent objectives. This document is well researched and based on his life-long familiarity with the problems at the grass root-level.

Ecodevelopment: A major problem facing India is that almost half of the country's land area is uncultivated (158 Mha out of 329 Mha). Being primarily an agricultural (76 per cent population) and rural (576000 villages) country, uncultivated land has to be brought under cultivation on account of a variety of environmental, social and economic reasons. Khoshoo has been intimately involved for the last two decades in revegetating barren alkaline land with community participation. The strategy has been essentially biological with low-engineering inputs. The results achieved have been remarkable and this work has been regarded as a "path finder". The message has spread to a large area involving many villages. This success story has now been documented. There has been a significant reduction in sodium levels with all-round amelioration of soil. The model has been a holistic one aimed at generating food, fodder, fuel, fibre, fertilizer, medicinals, aquaculture, small vocations and wilderness areas. It has enabled building up of confidence of the subsistence farmers. In the words of Prof. MGK Menon, FRS (Science Advisor to Prime Minister and Member, Planning Commission), "the Banthra experiment was significantly advanced under the dynamic leadership of Dr. TN Khoshoo. It is through his initiative that a small research experiment was converted into a large-scale field demonstration and trial. He must be congratulated on the innovative scientific approach adopted and the leadership he has provided.

Perspectives in Environmental Management: Today, there is a high degree of awareness about environment. Whereas awareness helps to highlight the problems, it alone cannot help in setting right the environmental damage. Inevitably, what must follow is a detailed scientific analysis so as to evolve strategies for solution of the problem. This would in turn lead to sustainable development.

The area of environment is indeed multidisciplinary and trans-sectoral. The environmental problems can be solved by involving mathematical, physical, chemical, biological, energy and engineering sciences. There is in fact, economics environment interdependence.

In India, dependence on renewable resources is considerable. A sound, long-term strategy is indeed for managing these wisely in order to prevent their non-

reversible degradation. This alone will ensure a minimum standard of living on a sustainable basis for India's teeming millions.

Tropical Forestry Action Plan (TFAP): Khoshoo was associated with the formulation of the TFAP, (WB, UNDP, FAO, UNEP) and a blue print for action, involving scientists, technologists, social groups and villagers, was prepared.

Environmental Policy for Sustainable Food Production: At the request of FAO, Khoshoo has prepared a comprehensive draft policy for sustainable industrial resource-rich agriculture in developed countries and subsistence resource-poor agriculture in developing countries. The underlying idea is to evolve environmentally sustainable agricultural productivity system.

Biomass in Energy and Environment: This is a detailed version of his 1982 paper, presented before the Indian Science Congress (Botany Section). The book is a well-researched document based on the premise that in unusually large number of villages in India, both the social and economic systems are primarily based on biomass production. The book deals with the intensification and diversification of biomass production and utilization in the context of a developing country. Such a thrust alone will help to rehabilitate the resource-poor, often landless, villagers at the grassroot.

Forest Tree Conservation and Production: Based on his well-known papers published in the *Journal of Genetics, Evolution* and *Journal of Heredity*, Khoshoo has produced a model for forest tree conservation and production in the Indian context. In essence, the model is also applicable to the reasonably resource-rich but technology-poor developing countries in the tropical belt where, of necessity, there is low-management for conservation of and production from forest stands. Here, initially tree improvement work has to be taken up on the principles of well known forest genetics. Genetically, forest stands' approach a situation found in nature where a high degree of genetic diversity exists in the populations. (See also Late Dr. PD Dogra's biographic account in connection with the improvement of forestry **practices in India on pages 29-55 of this volume).**

Khoshoo's model envisages four types of mutually supportive forestry, namely Conservation Forestry (for long-range ecological security and conservation of overall climate, water, soil and biodiversity), Agroforestry (to meet the needs of fuel, fodder and small timber of the rural poor), Industrial Forestry (to meet the escalating needs of paper, pulp, fibre and timber), and Re-vegetation Forestry (restoration of degraded land by trees). To close the gap between demand and supply, Khoshoo has also advocated Tree Crop Farming under Industrial Forestry. He has worked out in detail the characteristics (morphological, anatomical, chemical and genetical) for specific ideotypes for higher productivity for timber, pulp, fuel, and fodder types. These involve considerable inputs from science and technology and are based on the

premise that sustainable production is the best form of conservation of forest resources.

Environmental Concerns and Strategies: This is the second and enlarged edition and contains 54 lectures delivered by Khoshoo on environmental topics. The first edition of the book was used widely as a standard teaching material at many universities in India and the developing countries.

These lectures have been grouped under 10 broad areas ranging from an overview of the environmental problems to specific problems of pollution, mining and metallurgy, renewable energy, biotechnology, tourism, forestry, education, law and conservation. The lectures were delivered before equally varied audience, from scientists and technologists in professional academies, societies, universities, institutes and colleges, to planners, decision makers, and managers of industrial establishments and public sector undertaking, lawyers and members of non-governmental organizations.

In his foreword to the book, Dr. MS Swaminathan states, "It is widely recognized that the Indo-Gangetic Plains have potential for serving as a major breadbasket of the world. We also know now that unless the ecological degradation of the Himalayas can be arrested, the Indo Gangetic Plains could undergo severe desertification within the next 25 years. It is in this context that the present book containing various lectures delivered by Dr. TN Khoshoo is a timely contribution. Where there is no scientific analysis, there could be no well-planned action which could promote sustainable development. Dr. Khoshoo combines a remarkable breadth of vision and depth of knowledge. Coupled with these qualities is his broad humanism which has led to the growth of the first-rate scientist into a dedicated strategist for human survival. We are deeply indebted to him for taking the trouble to prepare so many well-informed and thought-provoking lectures and getting them published in this eminently readable form."

Under Utilized Plants and Animals: Some years ago, Khoshoo and Swaminathan were instrumental in starting an All India Coordinated Project on Ethnobiology involving more than 27 institutions in the tribal belt. Several workshops were held involving the various project groups. Based on these studies, Khoshoo prepared two volumes, one each on underutilized plants (50 species) and animals (34 species) which are at present collected from natural populations. However, these need to be cultivated or domesticated, often for use in drought-prone areas with water shortage and such other harsh climates. In many cases, agrotechnology has also been suggested (Publication information not available for these volumes).

Conservation of Biological Diversity: India is a rich Vavilovian Centre of Diversity of Germplasm of plants and animals relevant to agriculture, horticulture and animal husbandry with many species already in use and many useful genes having been

provided for genetic upgradation of the existing crop and animal species. Today, these species are highly endangered. Earlier, Khoshoo identified 12 ecosystems as biosphere reserves whose details were documented. He has now prepared a Trend Paper on the subject which was published by the Council of Scientific and Industrial Research and released on September 26, 1987. The paper discusses the problem in depth from scientific, technological, economic and political angles. It will lead to the preparation of a Policy Paper on the subject which by itself is likely to be a trend-setter for the gene-rich developing countries.

In view of the fact that the subject is becoming increasingly politicized, among other things, the paper discusses the following issues:

Prioritization, Continuous need for germplasm, Holistic approach in conservation, Commonality of interests between developing and developed countries, Genetic engineering and germplasm, Patenting of germplasm, Need for pragmatic approach, National Task Force on Conservation of Biological Diversity, and International Task Force on Conservation of Biological Diversity.

One important message of Khoshoo's paper is that the increasing depletion of economic wild plants and animals is due to over exploitation. The best strategy for such plants and animals is domestication based on genetic evolutionary considerations so that collection through "hunting-gathering" becomes costlier than their domestication. Added advantage would be that the poor people, for whom these plants (medicinal and aromatic) and animal (meat, fur, bones, etc.) are a vocation, would be helped. This would enable us to blend environmental and economic imperatives successfully, which is the essence of sustainable development.

According to Khoshoo such domestication fulfils all the four criteria of sustainability, namely (i) ensuring equity with social justice, because it would help the poor who depend on these plants and animals for their living; (ii) creating environmental harmony because it would help in the regeneration of endangered plant and animal species; (iii) being economically efficient, and (iv) developing local self reliance because it would generate wealth and make it possible to raise the raw material where it is needed the most, and at a low cost, with no violation of wildlife laws and elimination of the involved malpractices. Several steps taken by Khoshoo as Secretary to the Government of India, have now begun to bear fruit. One of these is for farming of animals that are in trade for the last several hundred years and have now got depleted. Second is the seed biology and tissue culture as production and conservation strategy.

Khoshoo's contributions in the area of environment are significant in as much as his approach and commitment have been to positive environmental action while taking note of the negative impacts. He has made significant contribution to environmental action at the grassroot level. He was committed to the cause of

science-based positive environmentalism. In the words of Dr. Swaminathan, Khoshoo was a "dedicated strategist for human survival".

Finally, he has been responsible to bring about environmental awareness in the country.

PERSONAL IMPRESSIONS AND ASSOCIATION WITH THE AUTHOR

I have had the good fortune of being associated with Late Dr. TN Khoshoo for over fifty-three years (1949 onwards), firstly as his student in B.Sc. Honours School in Botany at Panjab University when the university department was located at Khalsa College, Amritsar. He used to take our practical classes for cytology and gymnosperms. My experience with him was very exciting because he would take pains in explaining the morphological and structural details of conifers and spend hours together to help us in finding countable chromosome plates during the study of meiosis in different plants. In those days of late 1940s and early 1950s doing acetocarmine squashes was not an easy job both for the teacher and the students. It is at that time I developed interest in studies on chromosomes, the carriers of hereditary characteristics. Theory part of both Gymnosperms and Cytogenetics were taught by Late Professor PN Mehra who was a remarkable teacher. Both Prof. Mehra and Dr. Khoshoo inculcated in me the interest for knowing the natural vegetation of India and also to peep into their cytological evolutionary details. By gaining from the working style of the two teachers, I was able to make my life successful in due course of time. Dr. Khoshoo was busy with chromosomes of conifers and herbaceous flowering plants at that time. After my completion of B.Sc. (Honours School) course in Botany in 1951, I joined the Department for M.Sc. research work under the guidance of Late Prof. Mehra. At that time Prof. Mehra had initiated work on Chromosome of Ferns and Fern Allies with acetocarmine squashes, hitherto unknown in India till the publication of Irene Manton's book on the Problems of Cytology and Evolution in the Pteridophyta in which she mentioned about the newly invented technique of study of chromosomes in Pteridophytes. Including me, a number of students were doing simultaneously such work in different groups. Since Prof. Mehra himself used to be very busy and not easily available for consultation, we used to go to Dr. Khoshoo for solving our working difficulties in getting in ferns chromosomal countable preparations. This was not an easy task with plant groups having much higher number of chromosomes as compared to the flowering plants. Contact with Dr. Khoshoo in research was essential because of his long experience of working on chromosomes since 1946. His devotion to help and provide guidance was greatly valuable for us to get a good start in research because in those times not many research students would opt for chromosome research. After getting M.Sc. degree in 1953 I started Ph.D. work with Prof. Mehra and the process of consultation with Dr. Khoshoo continued for many more years. It was he who always encouraged us to publish our work and I myself owe my grateful thanks

to him for inspiring me to proceed further in research. I scrupulously followed in life his dictum of 'either publish or perish' in research.

By the end of 1957 after I had got married our relationship strengthened with contacts at family level. Mrs. Khoshoo has been a wonderful lady to take care of colleagues of Dr. Khoshoo especially the younger ones. We became colleagues after I joined the faculty in 1956. Dr. Khoshoo had been very liberal in providing consultation, literature and other help. He all through promoted the research on chromosomes in the department. The atmosphere was very friendly for work at Amritsar and Chandigarh. A group of young teachers (DS Loyal, myself and SC Verma) were centered around Dr. Khoshoo with brotherly bondage. We did very hard and extensive work which resulted in a large number of publications by each member of the group who looked to Dr. Khoshoo for advice, encouragement and help. For me the period of my association with Khoshoo was very productive academically. Then, in 1962 all of a sudden Dr. Khoshoo decided to leave Panjab University and he never looked back and went on proceeding further and further on the road to progress.

But during the period onwards from 1962 till 2002 there was not any communication gap between us. Dr. Khoshoo visited me at Punjabi University, Patiala several times for participating in symposia and conferences. During every visit Dr. Khoshoo appreciated the progress made by the Department of Botany (which I established in 1967) both for upgradation of research and teaching facilities and for raising academic standards. But my visits to Lucknow were more frequent since there were many occasions for me to meet him during conferences and symposia. During Dr. Khoshoo's tenure as Director, NBRI every time I went to Lucknow, there were many new vistas of progress to observe. The institute had made creditable research contributions in several areas. After his posting in New Delhi as Secretary DOEn & Forests, the efforts which he made to create public awareness of national environmental priorities, are highly appreciable and well-known to every one.

Meeting Dr. Khoshoo was delightful in the sense that he had a multi-faceted personality and one could learn from his many traits. Above all, hospitality and personal attention were the characteristics of both Dr. Khoshoo and his wife, Mohani Behanji as she would be called by us with reverence and affection. With him my friendship and charm to come to Delhi suddenly ended in 2002 with his sad demise. I have had no occasion to find Dr. Khoshoo in bad temperament. I learnt many good things in life from him and the most precious one was that one should publish one's results of research as soon as finalized. I greatly benefited by following this practice of his. At all times he had been a very kind and affectionate friend, not only to me but to many others who came in contact with him.

Dr. Khoshoo was a voracious reader and prolific writer. In his life time he did so much work, both organizational and academic, that very few people would be equal to him. He was a different category of scientist who combined his thinking and practicability into success. He was one, who utilized his determination and facilities available to him to the fullest. To make a success of a project he would establish contact at grass root levels. Being such a great scientist he had humility and kindness, a rare combination indeed. He was a deeply religious person, fond of listening to both classical and religious music. He was especially interested in listening to Gurbani from Sikh scriptures. Several years ago, he had asked from me such audio cassettes. He was gratified when he got them. He had varied interest in free time. Also enjoyed watching classical dances and listening to Urdu ghazals.

Summing up, I would say his main strength for his work was his wife, a very gentle and soft spoken lady. Of course he derived tremendous amount of backup and affection from his friends which he deserved so much.

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