JAMSHEDJI JIJIBHOY CHINOY

(1909–1978)

Elected F.N.I. 1974

CHINOY ERA would be the right name and not an exaggeration for the period 1935–78 in Indian Plant Physiology. It was Jamshedji Jijibhoy Chinoy who nurtured, dominated, guided and brought up with a loving care 'Plant Physiology' to the scientific horizon of India. The efforts he put in were tremendous, the difficulties he faced were titanic but what he achieved was a magnificent success and the service he rendered to the discipline will never be forgotten.

EARLY LIFE AND EDUCATION

Jamshedji Jijibhoy, the eldest son of Shri Jijibhoy Dadabhoy Chinoy and Smt Gulbanu J. Chinoy, was born on February 18, 1909 at Bhuj (Kutch) in Gujarat. His father died when young Jamshed was only four years old. His maternal grandfather, Pallonji B. Bhagaria, who took care of the child was responsible in many ways in moulding him in his formative years. Chinoy had a happy childhood till the age of twelve when his maternal grandfather died. He had his primary education at Alfred High School in Bhuj from 1915 to 1920 where he matriculated in 1925. His University education was financed by Lady Navazbai Ratan Tata, a great name in the Parsi Community in Bombay. Her magnanimity, humanity and benevolence left a deep impression on young Jamshedji and steered him to a career of teaching and research in science.

His post-graduate studies were done in the University of Bombay, where he distinguished himself not only as a Plant Physiologist of rare ability but also as an all round sportsman, winning many medals and shields as a swimmer, boxer, canoeist and cricket and tennis player. In 1932, he was awarded a Foreign Research Fellowship by the University of Bombay for higher studies in Britain. He worked under the guidance of Professor F. G. Gregory, an internationally reputed Plant Physiologist, at the Biological Laboratories of the Imperial College of Science and Technology, London, and obtained his Ph.D. degree in 1935 and the Diploma of the Imperial College of London (DIC) the same year.

RESEARCH CAREER

On his return to India, Chinoy spent some time in large-scale field experiments on dry land cultivation of wheat at the Godrej farm, Nasik, before his appointment

in 1936 as research assistant in the Agriculture College at Lyallpur, Punjab in a project on "Partial failure of American Cotton in the Panjab" financed by the Indian Central Cotton Committee. He was appointed in 1941 as Assistant Economic Botanist in the newly started Section of Plant Physiology in the Economic Botany Division at the Indian Agricultural Research Institute, New Delhi. From 1947 to 1959, he worked as Reader in the Botany Department of the Delhi University. He joined the Gujarat University at Ahmedabad in 1959 as Professor and Head of the Botany Department. He also worked as Director of the University School of Sciences from 1962 to 1975. Although he retired from active service in 1975, he continued as Professor Emeritus under the UGC sponsorship for two years till his death on May 12, 1978.

Throughout his forty-two year research career, Chinoy was deeply interested in both pure and applied research in Botany. He published more than 200 research papers in journals of national and international repute. His findings on the role of ascorbic acid in plant growth won him international fame. At the Gujarat University, Ahmedabad, he helped establish a strong school of Plant Physiology and many students worked for their doctorate degree under his guidance.

Chinoy worked on a wide variety of research topics in plant physiology.

Correlations between Growth, Metabolism, Development and Crop Yield

Chinoy and his coworkers collected data on a large number of varieties of wheat, oat, barley, linseed, gram, rye, wheat-rye hybrid (triticale) and other crop plants grown at different places in the country. They studied the major growth and yield characters of these plants such as rate of photosynthesis and respiration, height, tiller production, number of leaves, fresh and dry weights of stem, leaf, ear and root, number of ears, spikelets and grains, length of ear, weight of grain and correlated them with the length of the growth period. Also, under widely varying environmental conditions, the relationships between developmental processes, growth and yield were confirmed by subsequent experiments. The important conclusion from these researches was that most of the characteristics of different varieties were correlated with their developmental processes. Major physiological processes of a plant were closely integrated and interdependent phenomena, each of which affected the others markedly. The work of Chinoy established that the rates of production and utilization of regulatory substances were different in different varieties and these differences were linked with the development of the plant, which is either accelerated or retarded by changes in the environmental conditions.

Energy Requirement of Crop Plants

Chinoy, while working on correlations between growth and time of flowering of wheat varieties, observed that alterations in the rate of developmental process changed the growth pattern of the plant. He noticed that the photoperiodic responses of different varieties of wheat were correlated with the length of the growth period, thus suggesting a quantitative relationship between the amount of energy utilized by the plant and some of its major physiological processes. This was particularly evident in experiments with graded series of photoperiodic treatments given by placing the plants either in continuous light or in reduced photoperiod for 5, 10, 15, 20, 25, 30, 35 and 40 days besides growing themin normal conditions of light. Attempts were made to determine the amount of energy required by different varieties of wheat belonging to different flowering classes during their growth periods, when subjected to vernalization and photoperiodic treatments. Total number of light hours (Photo-quantum-P) as well as the sum of degrees of mean diurnal temperatures (Thermic quantum-T) of growth period (number of days from the date of germination or transplantation to the date of anthesis) were calculated for plants under different treatment combinations. The products of photo- and thermic-quanta of all varieties under different light and vernalization treatments were found to agree closely for a variety of plant under different treatments. This product was named *Photothermic quantum* of a variety. The difference between the photothermic quanta of unvernalized and vernalized plants of a variety was designated *Vernalization quantum.*

The quantitative relationship between the photothermic quantum, vernalization quantum and length of growth period of wheat had an important bearing upon physio-ecological and physio-genetical problems. The photothermic quantum (E) of a variety is the product of the photo-quantum (P) and its thermic quantum (T). The photo-quantum of a variety in its turn is a product of the mean diurnal photoperiod (P) and its growth period (F); while the thermic quantum is the product of the mean daily temperature (t) and the growth period of the variety. It therefore followed that :

$$E = PT = ptF^2 \quad \text{and} \quad \therefore F = \sqrt{E/pt}.$$

It would appear from the foregoing that if the photothermic quantum of a variety is known, the approximate length of the growth period can be worked out for any given environment from the above formula by knowing the daily mean temperature and the mean day length during its growing season.

Physiology of Inheritance and Selection of High-Yielding Varieties on the Basis of Flowering Time

Chinoy on the basis of these studies of correlations and energy requirements of plants, studied the inheritance of growth and developmental characters by making crosses between different varieties of crop plants belonging to different classes of flowering. Parental and hybrid generations of these crosses were studied by growing them not only under the normal environment of Delhi but also under different photoperiodic and vernalization treatments.

An important result that has emerged from this work is that the segregation of a growth character takes place differently not only in the F_2 plants of different crosses between varieties belonging to different classes of flowering but also in F_2 plants of one and the same cross under different photoperiodic and vernalization treatments.

Chinoy thus, concluded that hybrid plants show the same correlations between growth and development as differently flowering crop varieties and that their response to the change in environment is also similar.

On the basis of these investigations, a new concept of heredity was put forward by Chinoy. It was postulated by him that heredity was controlled by its potential in the cell which he designated as *'Heredity Quantum.'* It was further postulated that it consists of (*i*) a structural complex—'Nucleon'; (*ii*) the energy receptor complex—Energon'; and (*iii*) a developmental complex—'Metabolan.' Nucleon, composed of macromolecules with a vast reactive (adsorptive) surface, served as a template for the synthesis of DNA and RNA which in turn served as templates for proteins, enzyme proteins as well as primary products of nucleon-like ascorbic acid of the organism. 'Energon' was postulated by him to be the potential power of heredity quantum to harness external energy into the pyrophosphate bands of ATP. The rate of production of ATP would depend upon the rate at which photothermic energy is made available to the plant and its photosensitivity.

The 'metabolan' of the heredity quantum represents the potentiality of a plant for energy utilization, resulting in metabolic activity which manifests itself in visible growth and development. The energy of ATP pyrophosphate bands was thought to depend upon the utilization of ascorbic acid as an electron donor. It also depended on the maintenance of a reductive environment so vital for the syntheses of nucleic acids, enzyme proteins, high polymers of carbohydrates and molecules of moderate size. These complexes interact with one another during hybridization.

Chinoy concluded that energy requirements varied in different wheat varieties. An early variety having greater photo-sensitivity could complete its developmental process early, thereby utilizing its resources for early production of flowers, fruits and seeds. Consequently, tiller and leaf production as also the leaf dry-weight was reduced. A late variety, on the contrary, requiring comparatively more photothermic energy, has longer vegetative growth, resulting in larger number of leaves and tillers and greater leaf dry-weight.

Later, Chinoy studied the correlation between yield kernel weight and mean maximum temperature of the ripening period. The results led to methods of selecting wheat varieties which escaped drought as well as damage due to black rust.

Classification of Wheat Varieties on the Basis of Their Energy Requirement

Chinoy felt that an integrated system of classification could be based on correlations between physiological processes like growth, development, nutrition and regulatory mechanisms of plants belonging to different varieties, species, genera and families in relation to their energy requirements for these processes. On the basis of studies of these correlations, an integrated system of classification of different varieties in terms of their energy requirements was evolved. For instance, N. P. 165 was written as *Triticum aestiyum,* 4.31 (0.24); and variety vaneum yakub as *Triticum vavilovianum* 17.91 (2.75), where the figure outside the parenthesis stands for photothermic quantum of the variety and the figure inside the parenthesis as its vernalization quantum. From these constants, the vegetative period of a variety was calculated by the formula $F = \sqrt{E/pt}$ in any environment.

Physiology of Drought Resistance

The problem of evaluating drought resistance of a plant which is conditioned by several internal and external factors, is a difficult one. Attempts were made to measure the degree of resistance in terms of one single morphological (seed coat permeability) or one physiological (changes in enzymatic processes and water requirement index) property.

Chinoy carried out physiological studies of drought resistance for 33 years. His work from 1941 to 1977 at the Indian Agricultural Research Institute, New Delhi and subsequently at the Delhi University upto 1959, as well as at the Gujarat University from 1960 to 1974 was basically on the following lines : (*a*) study of a collection of wheats grown on irrigated and 'dry' land; (*b*) determination of varietal resistance to wilting at different stages of growth and development; (*c*) determination of varietal resistance to wilting after synchronization of growth and developmental stages by means of vernalization and photoperiodic treatments; (*d*) presowing hardening treatment of seeds with a view to determining its agrobiological value for Indian conditions; and (*e*) study of protoplasmic and other internal factors determining drought resistance.

Drought Intensity Formula

A method of drought intensity determination was developed by Chinoy in 1960 and during 1964–67. The formula

$$I = K\ t/m,$$

where I is the drought intensity, m is per cent soil moisture during the period of wilting, t is temperature during the same period and K the number of days in the wilting season, was put forth by him.

Experiments with wheat varieties belonging to different flowering classes, subjected to various combinations of vernalization and photoperiodic treatments, showed that when a synchronization of growth and development stages in different varieties was brought about either by accelerating or retarding their flowering, the difference in response to wilting of early or late flowering varieties was eliminated to a considerable extent.

These facts led Chinoy to the conclusion that drought resistance in crop plants is inseparably bound with its major growth and developmental processes as well as with the environmental conditions prevalent during the growing period. Consequently, drought resistance could not be considered as a separate unrelated heritable characteristic.

Pre-sowing Hardening Treatment of Seed for inducing Resistance to Drought and Salinity

Chinoy and his coworkers gave extensive trials to the original method of

Henckel and Kolotova (1934) of presowing hardening treatment for inducing resistance to drought and salinity. The important results obtained by them were :

(*i*) Pre-treated plants gained an appreciable advantage over controls in the seedling stages.
(*ii*) Pre-treated seeds were superior to untreated ones in their capacity to extract moisture from the atmosphere.
(*iii*) The hydrolytic activity of amylase was greater in the pre-treated series compared to controls.
(*iv*) There is a sharp fall in the starch content of pre-treated seeds.

Field experiments carried out at different places with pre-treated and control seeds indicated in some cases, an increase of 25 per cent in grain yield per acre.

Correlations between Intensity of Rust Infection and Temperature and its Bearing upon Yield and 1000 *Kernel Weight of Wheat*

Chinoy was interested in physiological approach to the problem of rust resistance in wheat with respect to its growth and yield. He carried out nearly 3,000 determinations of the intensity of rust infection as well as its effect upon yield. The data showed that the yield was not appreciably reduced in early flowering varieties (100–120 days) even under conditions of virulent infection. As the length of vegetative period increased from 100 to 170 days, the mean maximum temperature of ripening period of varieties in different classes rose from 77° to 96°F and the yield as well as 1000 kernel weight progressively fell with the lateness of the variety.

From such physiological studies he concluded that a practical solution of the problem would be in sowing early flowering varieties at the optimum time in the growing season namely, from middle to end of October. Under these conditions flowering takes place early (second half of January) and a greater portion of grain development precedes the onset of rust infection. Also, grain-ripening takes place in a temperature range that is most conducive for grain-filling processes.

Physiology of Flowering

Evidence regarding the universal presence of gibberellins and anthesins in higher plants is not at all conclusive. During the last nineteen years of his research career, Chinoy and his collaborators undertook work on metabolic drifts of regulatory substances, of which the most important was ascorbic acid (AA). The endogenous content of AA reached a high level earlier in early flowering varieties, synchronizing with change in the growing point from the vegetative to the reproductive state. Also it was noticed that a high level was attained earlier when a late flowering variety was made to flower early by vernalization. Chinoy, Singh and Sirohi in 1957 further found that the rate of utilization of AA also increased considerably during the period of reproductive differentiation. Concomitant with high AA content was rise in the contents of nucleic acids, proteins and carbohydrates as also in ATPase activity. On the basis of the above-mentioned work, Chinoy propounded the 'ascorbic acid-nucleic acid-protein metabolism' concept of flowering as outlined below :

Under thermo- and photo-inductive conditions, production and utilization of AA takes place at an enhanced rate, thus producing a highly activated metabolic state in the shoot apex at the time of floral induction as well as subsequent reproductive differentiation. Increased electron flow augments ATP formation and consequently DNA and RNA are synthesized at faster rates leading to enhanced syntheses of proteins and enzyme-proteins. The above-mentioned activation of metabolism results in quicker laying down of growth centres and cell division and enlargement processes. A profound change in the differentiation pattern is, thus, brought about leading to the formation of reproductive organs. At a certain critical stage, in some cells the synthesis of nuclear constituents gains a precedence over that of cytoplasmic and cell-wall materials and thus, change in the norm of mitosis is brought about leading to meiotic divisions.

Later, not only the confimatory evidence on the increased production and utilization of AA during floral induction had been obtained but also considerable data on bound AA (ascorbigen) content, special peroxidase activity leading to the formation of free-radical of AA and formation of charge transfer complex of AA with macromolecules was obtained from a number of plant species. These substances remained at appreciably higher levels at the time of floral induction and more so during the entire period of reproductive differentiation. The most noteworthy finding relating to AA metabolism of shoot apex was the pronounced ability of AA to form complexes with DNA, proteins and perhaps other organic molecules of moderate size. Chinoy later obtained such complexing of AA with DNA *in vitro*. This led him to visualize the following mechanism underlying floral induction and differentiation.

It was proposed by him that AA undergoes monovalent oxidation in aerobic condition with the help of a special peroxidase and produces a powerful reducing agent, monodehydro-ascorbic acid (MDHA), which being a free radical, serves as an electron donor in the biosynthesis of macromolecules. Photophosphorylation as well as oxidative phosphorylation are also energised by the flow of electrons from MDHA, thus, augmenting the pool. Dehydroascorbic acid (DHA) resulting from the loss of an electron from MDHA is again reduced to AA with the help of reductase.

The further presumption was the nucleoprotein complexes with AA forming a charge transfer complex. The direct flow of electron energy taking place in the charge transfer 'liberates' the activated form of DNA from protein (histone). Further complexing of DNA with AA leads to the overlapping of their electron clouds and consequently exchange of orbitals in the mobile electrons from one to other. This charge transfer further activates DNA breeding free radicals of the nucleotides, which in turn activates the energy trapping and utilizing potential of the genic material.

Thus, the energies of (*i*) the bond, (*ii*) the free radical and (*iii*) the charge transfer complex are utilized for the production of RNA molecules of different types at ever accelerating rates, thus paving the way for increased production of structural proteins and enzyme proteins during the period of reproductive differentiation. In fact, the onset of meiosis is caused by a change in the rhythm of nuclear and protoplasmic processes participating in energy regulation and consequently in the formation of new cells and growth centres at enormously intensified rates.

Role of Auxin and Gibberellin in the Synthesis of AA

Work in Chinoy's Laboratory for about twenty years, highlighted the importance of AA metabolism in growth and flowering and the role of auxin and gibberellin also became clearer in the light of their catalytic function in the synthesis of AA. It was shown in 1959 that biosynthesis of AA from sucrose was catalysed by indole-3-acetic acid (Chinoy & Nanda, 1959). This hypothesis was further tested in a number of plant materials like coleoptile and root tips of *Triticum aestivum* cv. Arnej 624 and those of *Avena sativa* cv. Victory (Svolaf) as well as dry excised embryos of *Triticum aestivum* cv. Rival (Svalaf) and those of *Arachis hypogea* cv. A.H. 334 by growing them in various concentrations of sucrose and growth regulators like AA, IAA and gibberellin. Although all the three growth regulators promoted growth in the explants, their effect was best felt when sucrose of a higher concentration (1%) was added to the medium. It was clearly seen from the results that the biosynthesis of AA in the explants is catalysed by the addition of IAA as well as gibberellin in the presence of one per cent sucrose. Simultaneously, the utilization of AA is also appreciably increased by the presence of these growth regulators.

He proposed the following steps in the initiation of growth in a germinating embryo or a root or a coleoptile explant : (*a*) AA's presence increases the imbibing of water; (*b*) AA activates the enzymic systems responsible for the mobilization of reserve substances; (*c*) simultaneously auxins released from bound state catalyze the AA synthesis; (*d*) with the emergence of seedling above the soil and chlorophyll synthesis produces further AA; (*e*) in spite of its increased utilization, the reductive atmosphere which is conducive for synthetic processes in plants increases due to the rising concentration of this powerful agent of the redox system. (*f*) AA acts as an electron donor in photosynthetic and oxidative phosphorylations with which the formation of ATP is coupled; and (*g*) it creates a favourable redox balance for the synthesis of nucleic acids, proteins, enzyme-proteins and cell wall constituents, thus enabling the twin processes of cell division and enlargement to proceed at faster rates.

Role of AA in Crop Production

Alongwith the understanding of mechanism of AA's involvement in the plant growth and development, Chinoy also collected a mass of data on the interaction between AA and auxin, exogenous application of AA to the shoot apices of plants, biosynthesis of AA by different organs of plants as well as on the AA content and its utilization during the course of growth period of different crop plants such as *Triticum, Hordeum, Avena, Secale, Triticale, Cicer, Cajanus Arachis, Linum* and others grown under different photoperiodic and vernalization treatments, also point to the important role of AA in growth and development.

On the basis of foregoing evidence, a simple pre-treatment of seed with AA was developed by Chinoy. It was found to accelerate germinative process as well as growth and yield of mature plants.

Method of Pre-Treatment of Seed with AA developed by Chinoy

One mg of seed was taken and soaked in 400gm of cold water in which 10–20mg of AA was dissolved. The seeds were continuously stirred and after they had absorbed all the liquid, they were covered with wet cloth and kept in moist condition for about 6–8 hours, with frequent stirrings at intervals of 10 minutes. The seeds with hard seed coats were kept under moist conditions for longer durations. After the end of wet period, seeds were spread to dry in a cool shady place for 48 hours. The dried seeds may again be put in a fresh solution of AA to repeat the above treatment 2–3 times. As this pretreatment raises the water as well as mineral absorbing capacity of plants, a higher nutritional level in the soil was recommended to be essentially present in order to derive the maximum benefit of seed pre-treatment. This seed pre-treatment was also found to be a protective measure against seed-borne diseases. A number of varieties were tried by Chinoy and the results showed an increase in yield from 7 to 33%.

Honours

Chinoy received recognition from various national and international scientific institutions. He presided over the Plant Physiology Section of the IX International Botanical Congress held at Montreal, Canada in 1963. The X International Botanical Congress at Edinburgh in 1964 called him as a special invitee. He was a visiting scientist at various biological laboratories in Netherlands, England, France and Germany. He was invited by the German Academy of Science to deliver lectures on his research work. Chinoy was called to preside over the meetings of such distinguished gatherings as International Symposia on Arid Zone Problems held at Bhavnagar, 1965; International Seminar on Tissue Culture held at Baroda in 1965; International Seminar on Plant Growth Substances held at Calcutta in 1967 and Physiology of Differentiation in Plants held at Simla in 1971. He was one of the leading scientists invited to participate in the Seminar on 'Cellular and Molecular Aspects of Floral Induction' at Liege, Belgium in 1967. As an Honorary Vice-President of the XII International Botanical Congress at Leningard, USSR in 1975, he was awarded a medal for best research. He was the patron member of the Indian Society for Plant Physiology which he served in the capacities of Secretary, Vice-President and President. His elections as Fellow of the Indian National Science Academy and National Academy of Sciences in 1974 and 1975 respectively were recognitions of his contributions to science. More recently, in 1975 Chinoy got the *Rafi Ahmed Kidwai Award* for research in Agricultural Botany and Plant Physiology.

Personal Life

On November 5, 1938, Chinoy was married to Roda, daughter of Shri Rustam D. Khambata. She helped him in great measure in his research career and her support, understanding, inspiration and encouragement went a long way in raising him to distinction. The Chinoys were blessed with three sons and two daughters. While one of his sons, Major N. J. Chinoy, has a record of thirteen years service in the Indian Armed Forces, his elder daughter Dr (Miss) Niloufer J. Chinoy adopted a research career and is a Reader in Zoology at the Gujarat University. Unfortunately, one of his sons died at the young age of 32 in 1977 and this was a great blow to him.

Chinoy was a devoted husband and father who adored his family. He was an avid gardener. He inculcated in his children a love for nature at a very early age. The atmosphere at his home was happy, congenial and conducive for the attainment of high academic pursuits.

An Inspiring Personality

He was an inspiring personality, a noble and compassionate person who always lent a helping hand to the poor and needy. The greatest contribution which he made to science was to inspire young minds and mould them in the pursuit of science. He left a lasting impression on the minds of his students, who felt the fulfilment of the saying 'one lamp lights another, nor grows less, so nobleness enkindleth nobleness.' His motto was "Work is worship" and very often he used to quote :—

"*Honour and shame for no condition arise*;
Act well thy part and therein all the honour lies."

Undoubtedly, Chinoy lived upto that dictum.

K. K. Nanda
Rajiv Kumar Sharma

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