ASPB Pioneer Member

Jitendra P. Khurana

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Professor Dr. Jitendra P. Khurana, an internationally highly acclaimed Indian scientist, passed away at the age of 66.

Jitendra P. Khurana during the 4th International Conference of Duckweed Research and Applications organized at the Central University of Kerala in 2017 where he served as Co-President.

Jitendra P. Khurana did B.Sc. from Shahid Bhagat Singh College, affiliated to University of Delhi, India in 1973. He then moved to Kurukshetra University, India in 1973-1975 for his post-graduation (M.Sc Botany). His friends at Kurukshetra University fondly called him Paul, describing him as an affable colleague. He entertained them with melodious songs. He was a passionate photographer, who would click his classmates using his Yashica Camera, but rarely himself.

JP Khurana third from left, looking at the algal collections at Rameshwaram, Tamil Nadu, during their botanical excursion as a student of Kurukshetra University, ca. 1974.

A group photo with his Masters' classmates from Kurukshetra University. JP Khurana is in the last row, third from left, ca. 1975.

In 1975 he joined the Department of Botany, University of Delhi as a doctoral student with Prof. Satish C. Maheshwari. During his Ph.D. (1975-1982), he was strongly influenced by his academic teacher S. C. Maheshwari to focus on duckweeds.

In his first research projects, he investigated the species *Lemna aequinoctialis* (then referred to as *Lemna paucicostata*), especially clone 6746 (a short-day plant from California, which he obtained from R. Cleland, USA) and LP6 (now registered under the ID 9601; a day-neutral plant, which he collected in 1976 in Delhi). Under otherwise non-inductive conditions, salicylic acid or aspirin application resulted in 90 – 100 % flowering in both clones mentioned above (Khurana and Maheshwari, 1978). Importantly, high concentrations of Ca^{2+} were found to be required for these effects (Khurana et al., 1988a). In clone 9601, they observed an additive effect of benzylaminopurine (a cytokinin) and the chelator EDTA without changing the critical day length (Khurana and Maheshwari, 1983a, b). Application of 8-hydroxyquinoline (a copper chelating agent) to the clone 9601 induced flowering, and this effect was independent of the day length. Interestingly, they found that the content of Cu within the plants increased strongly under these conditions (Khurana and Maheshwari, 1983b). In the short-day clone 6746, he showed that the application of 8-hydroxyquinoline reduced the critical dark period by at least two hours. Analysis indicated that the contents of both Cu and Fe were remarkably increased in these plants (Khurana and Maheshwari, 1984). Subsequently, increasing the Fe concentration applied to clone 9601 to tenfold resulted in flower induction, especially in the presence of the strong Fe-chelator EDTA, which improves the Fe availability for plants. Also, in *L. aequinoctialis* 9601, there was a 12% increase in flowering when Fe and EDTA increased by about tenfold (Khurana et al., 1986c). However, they discovered that replacing EDTA with equimolar concentrations of EDDHA resulted in a dramatic increase to 90 %

flowering. Strong effects were also observed after applying some cytokinins in the presence of high Fe concentrations (10^{-4} M). At normal levels of Fe, however, cytokinins did not have any effect on flowering, regardless of the presence or absence of EDTA (Khurana and Maheshwari, 1986a). Researching with *L. aequinoctialis* 6746, they found that flowering could be induced by tannic acid (10^{-5} M) and some catecholamines (10^{-4} M) under strictly non-inductive photoperiods, even in continuous light (Khurana and Maheshwari, 1986b; Khurana et al., 1987). Similar effects, i.e., induction of flowering in the short-day plant 6746 even in continuous light, were observed after cAMP application, whereas 5′-AMP and 5′-ATP had very weak effects (Khurana et al., 1988c). The level of cAMP has been estimated in this clone (Gangwani et al., 1991) and cyclic nucleotide phosphodiesterase have also been isolated from clone 6746. Jitendra P. Khurana together with others showed that its enzymatic activity depends on calmodulin which could explain the effect of the calcium concentration during flowering (Gangwani et al., 1994). The role of NO in the induction of flowering was confirmed using pharmacological a pproaches: NO donors sodium nitroprusside (SNP), S-nitroso-N-acetyl penicillamine (SNAP), and 3-morpholinosydnonimine (SIN-1) induced flowering in L. aequinoctialis 6746 (a short-day strain) and in L. aequinoctialis LP6 (a photoperiod-insensitive strain) under non-inductive conditions (Khurana et al., 2011).

The influence of several amino acids on flowering induction was investigated by Prof. Khurana with clone 9601. The strongest effects (80 % flowering) were observed after applying glutamate or aspartate. Effective concentrations were between 5 x 10-7 and 10-5 M, indicating that they likely have a regulatory role rather than simply acting as metabolites (Khurana et al., 1988b).

J. P. Khurana together with S. C. Maheshwari at the University of Delhi South Campus in 2014.

Also, in *S. polyrhiza* (clone SP20), JPK found that flowering was induced by salicylic acid (5×10^{-5} M), most probably the first report about this species flowering in vitro (Khurana and Maheshwari, 1980). However, an optimal flowering response is obtained only when compounds such as EDDHA or benzoic acid are supplied. Salicylic acid induced flowering only in the simultaneous presence of EDTA (Khurana and Maheshwari, 1986d).

Professor Khurana also investigated flowering in the duckweed species *Wolffiella hyalina* 7378 (Egypt; collected by M. Mahdi ca. 1960, Landolt Duckweed Collection) and *Wolffia microscopica* 9276 (Delhi, India; collected by Khurana/ Maheshwari).

First investigations of *W. hyalina* by JPK indicated that this clone does not flower when cultivated in a broad spectrum of common nutrient media and in any light regime and even in the presence of several chelators like EDTA. However, the application of 10^{-5} M salicylic acid under short-day conditions (< 13 h daylight) induced profuse flowering in this clone. It was concluded that the action of salicylic acid is hormonal in nature rather than via chelation of metal ions (Tamot et al., 1987).

J.P. Khurana (left) together with KSS and KJA hunting Wolffia microscopica in Manouli, Haryana, India in October, 2014 in an effort to replace the lost clone 9276.

Wolffia microscopica 9276 is a short-day plant, but Dr. Khurana showed that flowering can be induced under long-day conditions by exposure to salicylic acid and similar compounds in the presence of EDTA. It has been concluded that the effect cannot be due simply to the chelation of metal ions and perhaps the salicyl moiety itself exerts a specific effect (Khurana and Maheshwari, 1983c). Flowering in *W. microscopica* could also be induced, under non-inductive long days, by 8-hydroxyquinoline resulting in 75% flowering at 5×10^{-6} M

(Khurana et al., 1986c). Unfortunately, clone 9276 was lost later on, but the species was rediscovered and further investigations were started together with J.P. Khurana and S.C. Maheshwari (Sree et al., 2015). Moreover, a historical overview of this species was published a month before Prof. Khurana passed away (Sree et al., 2021). Prof. Khurana's love for flowers was not only limited to laboratory research on microscopic flowers of duckweeds. He always took special care and interest, over the years, to keep up the floral beauty of the South Campus, University of Delhi.

The research activity of J.P. Khurana was not completely restricted to duckweed species (Tyagi and Sopory, 2021). In 1985 he moved to the Smithsonian Institute, Washington, USA, as a post-doctoral fellow in the lab of Charles Cleland. In 1986 he went to Michigan State University to work with Kenneth Poff in the newly emerging area of physiological analysis of Arabidopsis mutants. At MSU, he isolated a phototropism deficient mutant JK224 that Winslow Briggs' laboratory had later used to isolate the phototropin 1 photoreceptor. He then returned to India in 1988 to join the newly established department of Plant Molecular Biology at University of Delhi, with which he was associated till his demise. He was a key faculty to establish this department as a leading center of Plant Molecular Biology for teaching and research in India. Then, his lab mainly focused on functional genomics of plants, using Arabidopsis, wheat, and rice. However, he kept his interest in duckweed alive and painstakingly maintained all clones in a stock collection by regularly culturing them for all these years. One of the authors, KSS is fortunate to now host his stock collection comprised of clones from all five genera of duckweeds. His interest in duckweeds was also demonstrated when he served as the co-president of the 4th International Conference on Duckweed Research and Applications organized in Kerala in 2017.

He played a key role in sequencing three important crop genomes, rice, tomato, and wheat, as an Indian partner in International consortia. His work on cryptochromes in mustard and rice flowering and identifying stress- and auxin-related gene families is well recognized and well-cited by the international community. Even during the last year, despite ill-health, he was busy finalizing his research papers on developmental aspects of rice. In total, he published 23 papers about duckweeds with the most recent one published in September 2021, 30 with wheat, 52 with rice, and 68 with Arabidopsis thaliana (Web_of_Science).

Dr. Khurana also tirelessly worked on Institution building and promoting and nurturing plant science in India. He served as a member and chairman of several DBT, CSIR, and DST committees in India. He was actively involved with all National Science Academies and served as vice-president of INSA, Delhi. He also served as the Pro-Vice-Chancellor for the University of Delhi (2016-19). Most importantly, his Alma Mater recognized his seminal work with the Goyal Prize in Life Sciences by Kurukshetra University, Kurukshetra, and Nishtha Dhriti Satyam Samman by University of Delhi, India.

He was a very good friend, mentor, and Scientist. Despite attaining very high positions and being busy with administration and research, he remained in contact with his teachers, students, and friends. One could reach out to him for help, and he would do his best to help. Any one who would have met him will surely remember his pleasant smile. He is survived by his wife Paramjit, a renowned plant molecular biologist, son: Sachin, and daughter: Ridhi.

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