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FIFTY YEARS OF BOTANICAL RESEARCH AT THE INDIAN AGRICULTURAL RESEARCH INSTITUTE

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1. INTRODUCTION

The Indian Agricultural Research Institute, New Delhi, popularly known as the Pusa Institute, was founded in 1905 at Pusa in North Bihar and its Golden Jubilee is being celebrated this year. Economic improvement of crop plants by breeding new and superior varieties has been one of the most important activities and achievements of the Institute during its fifty years of existence. It is hence apt that some of the work done at the Institute in the applied and fundamental aspects of genetics and plant breeding is briefly summarized at this stage.

2. BOTANICAL RESEARCH AT THE INSTITUTE

Three distinct phases can be recognized in the evolution of botanical research at the Institute. In the first period, ranging from 1905 to 1935, work was carried out in a Section of the Institute under the guidance of eminent Scientists like Sir ALBERT HOWARD, Mrs G. L. C. HOWARD and Dr F. J. F. SHAW. In the second period, extending from 1936 to 1945, the venue of the work was shifted to Delhi as a result of the severe earthquake of 1934 which damaged a major portion of the laboratories of the Institute at Pusa. During this period, when Dr B. P. PAL, the present Director of the Institute, assumed charge of the Botany Section, results from cytogenetic studies were used in the formulation of breeding procedures and a small unit was established for plant physiological investigations. The third period commencing from 1946 has been

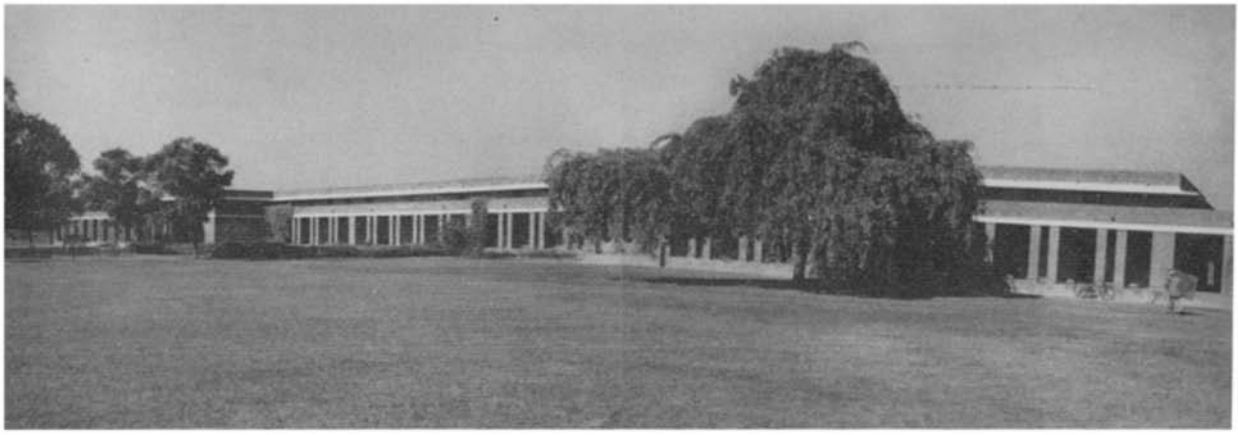

FIG. 1. LABORATORY OF THE DIVISION OF BOTANY, INDIAN AGRICULTURAL RESEARCH INSTITUTE, NEW DELHI

marked by a considerable expansion of the staff and facilities available for Botanical Research at the Institute. The section of Botany was raised to the status of a Division with well-organized sections of Genetics and Plant Breeding, Cyto-genetics, Crop Physiology and Plant Introduction and Systematic Botany. The main Division has now several sub-stations for carrying out crop breeding work on a regional basis. PAL and RAMANUJAM (1944) have reviewed some of the botanical work carried out at the Institute.

3. BREEDING NEW VARIETIES OF CROP PLANTS

The potentiality for crop improvement through planned breeding work has been investigated in many of the important crop plants of India. As a result, improved strains have been produced in the following crops: wheat, rice, barley, oats, pigeon-pea (*Cajanus cajan*), gram (*Cicer arietinum*), *mung* (*Phaseolus aureus*), *Urid* (*P. mungo*), lentil (*Lens esculentum*), peas, sugarcane, linseed, *Sesamum*, safflower (*Carthamus tinctorius*), chillies, *Hibiscus*, maize, potato, mustard, and several vegetables.

Details concerning the new varieties produced in some of the crops are listed below:

Wheat: At the time improvement work was started in this crop at Pusa, the varieties grown by the farmers were all mixtures of different types. Hence several outstanding new strains could immediately be produced by pure line selection. The evolution of the Pusa wheats, as they were called (the improved varieties bred at the Institute are now designated as N.P. or New Pusa types) was widely appreciated since they were released at a period when the reputation of Indian wheat was low in the export market and there was a general feeling that high quality wheats could not probably be produced in India. The milling and baking tests carried out with the Pusa wheats in England showed that they are comparable in quality to the best north American spring wheats and the variety Pusa 4 was awarded prizes for grain quality at several exhibitions held abroad. The popularity of the Pusa wheats among the Indian farmers could, to some extent, be judged from the fact that the variety Pusa 52 had by 1943 replaced the local strains to the extent of 80 % in the state of Bihar alone.

Although the early Pusa strains fulfilled a great need of the wheat-growers, the problem of combining high yield and good quality with resistance to major diseases remained unsolved. This work was initiated by Dr B. P. PAL in 1936 and has been in progress under his guidance since then. For this purpose, a large collection of indigenous and exotic wheats including many wild and cultivated species of *Triticum* and allied genera was built up and evaluated for economically useful characters. The material with desirable genes was utilized in an extensive hybridization programme. By selection among the hybrid progenies, a new series of varieties (the N.P. 700 series) tolerant to rust and resistant to smut infection, has been developed. Among these new strains, N.P.710 has shown adaptability to a wide range of soil and climatic conditions and has done well in the states of Uttar Pradesh, West Bengal, Saurashtra, Madhya Bharat and Bombay. N.P.718 and N.P.761 are relatively early in maturity; the former is well-suited to Delhi State, Rajasthan and parts of Madhya Bharat, while the latter has given a good performance in Bihar and Orissa. In high altitude regions, N.P.770 has done well.

Several varieties with a high degree of resistance to one or the other of the three rusts

FIG. 2. EARS OF THE IMPROVED WHEAT VARIETY, N.P. 718

(black, brown and yellow) have also been evolved as a result of crosses between certain foreign and local wheats, screening the hybrid populations for resistance under conditions of artificial infection and selection for economic characters. Thus, N.P.789 and N.P.790 are practically immune from the attack of all the races of black rust prevalent in India; N.P.783 and N.P.784 are highly resistant to different races of brown rust and N.P.785 and N.P.786 to many races of yellow rust. By further planned breeding, the variety N.P.809 which shows resistance to all the three rusts and which has given an excellent field performance in the entire north-western hilly tract, has been evolved. Three other strains N.P.797, 798 and 799 also possessing resistance to the three rusts are promising in the plains. The wheat breeding work at the Institute has been reviewed by PAL (1944; 1948 and 1954).

Sugarcane: The work of the Sugarcane Breeding Station at Coimbatore, which was formerly a Sub-station of this Institute, has been comprehensively reviewed by VENKATARAMAN (1938). The Sugarcane Station was established in 1912 and the able work of Dr BARBER and Sir T. S. VENKATRAMAN in evolving suitable seedling canes (known as Co. canes) has greatly benefited the Indian cane grower and sugar industry. The work at Coimbatore represents the first attempt in the sugarcane world at improving the sub-tropical type of canes. By crossing the noble canes (*Saccharum officinarum*) with the wild cane (*S. spontaneum*) and by a subsequent process of "nobilisation", types with adaptability to difficult subtropical conditions and with resistance to certain pests and diseases were evolved. It is admitted on all hands that the Co. canes have appreciated the cane yields by at least 50 per cent both in the north-Indian belt and the

tropical belt of Bombay and Madras. Some of the important Coimbatore cane varieties are Co. 290, Co. 312, Co. 331, Co. 370, Co. 419 and Co. 421.

Potato: By selection in progenies of crosses between European and local varieties, hybrid strains suitable to the hills and plains of East Punjab, Uttar Pradesh, Bihar and West Bengal were produced. Several hybrids resistant to *Phytophthora infestans* were evolved from the cross *Solanum demissum* × *S. tuberosum.* All this material was made available to the Central Potato Research Institute when it was organized in 1948. The potato breeding work carried out at the Institute has recently been summarized by PAL and PUSHKARNATH (1951a). A monograph relating to the identification and classification of the potato varieties grown in India has been published (PAL & PUSHKARNATH, 1951 b).

Linseed: Several varieties with good yield and oil-content were evolved at Pusa. However, all these varieties were susceptible to rust attack. Crosses were hence made between the Pusa strains and some varieties from Australia which were immune from the races of rust prevalent in India but which were late in maturity. By testing the hybrid populations under conditions of artificial infection, 78 lines immune from rust have been isolated. Some of them, e.g. N.P.(R.R.) 5, 9, 45, 262, 439 and 440, have performed well in trials conducted in several states with reference to yield and oil content and resistance to rust attack (DESHPANDE and JESWANI, 1954).

Pigeon pea: As a result of crosses made to combine good cooking quality with resistance to wilt, several new strains, e.g. N.P.C.15 and N.P.C.38, have been produced.

Tobacco: A new selection, Amarcho 5, from an introduced variety of cigarette tobacco proved much superior to Harrison's special, a variety popular in India for fluecuring, both in the time taken for curing and the percentage of first-grade yellow leaf. An improved type of chewing tobacco, N.P.70 has also been released for distribution. In the *hookah* tobacco (*Nicotiana rustica*), two high yielding selections, N.P. 219 and N.P.220, have been evolved through inter-varietal hybridization. Several interspecific hybrids have also been produced and studied with reference to economic characters like resistance to mosaic and leaf-curl, resistance to frost and nicotine content. The cytogenetic behaviour of these hybrids and the amphidiploids obtained from them was also studied (RAMANUJAM and JOSHI, 1942).

Maize: The improvement of the Indian flint varieties of maize by the "hybrid corn" method has been taken up since the past few years. The combining ability of many strains has been evaluated and promising single and double crosses have been built up. Also, high yielding hybrids suitable for cultivation in the hills and plains of India have been found in the double cross material of dent corn obtained from the United States. Fundamental work on maize breeding techniques and production of homozygous diploid breeding lines by doubling the chromosome number of monoploids isolated with the aid of suitable marker genes, have also been recently initiated.

Vegetables: Improved varieties have been produced in many summer and winter vegetables. In brinjal (*Solanum melongena*), tomato (*Lycopersicon esculentum*) and *bhindi* (*Abelmoschus esculentus*) interspecific crosses have been under study with the object of producing varieties with prolonged growing season and possessing resistance to certain diseases and pests. From the progeny of the cross *L. esculentum* × *L. pimpinellifolium*, an early-ripening variety (Pusa Red Plum) possessing high vitamin and

FIG. 3. A RUST RESISTANT LINSEED TYPE EVOLVED AT THE INSTITUTE

sugar contents has been bred. In *bhindi*, amphidiploid plants from the cross *A. esculentus* × *A. tuberculatus* (a newly described wild species possessing resistance to the yellow-vein mosaic disease which causes considerable reduction in the yield of cultivated *bhindi* – see PAL *et al*, 1952) are being backcrossed to the cultivated varieties to evolve a high yielding strain resistant to yellow-vein mosaic. Several species like *S. incanum* and *S. xanthocarpum* are being used in breeding brinjals resistant to the stem borer.

The possibility of obtaining increased yield through utilizing hybrid vigour has been investigated in several vegetables. A brinjal hybrid, named Pusa Purple, obtained by

crossing the varieties Muktakeshi and Clustered White gave significantly higher fruit yields than the parents and other commercial varieties. In onion, cytoplasmically controlled male sterile lines are being isolated.

4. Plant introduction and systematic botany

A collection of 7623 exotic varieties of crop plants has been built up and their performance has been assessed under Delhi conditions. In wheat alone, nearly 2500 foreign varieties are being maintained. One wheat variety, Ridley, has proved useful for direct cultivation in the hilly tracts of north India. Several introduced wheat varieties have been profitably used in breeding rust-resistant varieties suitable for the plains and hills of India. Other examples of useful material introduced from abroad are the tomato variety Sioux, the garden pea varieties – Early Badger, Bonneville and Delwiche Commando, the onion varieties Bermuda Yellow and Texas Grano, the sweet potato variety F.A. 17 and the water-melon variety New Hampshire Midget.

The task of identification and classification of the large number of introduced and indigenous plant collections is done by the Systematic Botany section. Samples of imported food grains are examined for the presence of seeds of poisonous plants. Work is in progress to assess the performance under Dehli conditions of *Kochia indica* (family Chenopodiaceae), which has been reported to be very valuable for desert reclamation work in the Middle Eastern countries. A herbarium of varieties of crop plants and weeds of cultivated fields is being built up and now consists of about 5000 specimens. Systematic studies of species and varieties of important food plants are in progress with reference to their origin and classification (Chatterjee, 1951).

5. Cytogenetics

Studies on basic problems like species origin and inter-relationships as well as applied work like breeding better varieties of crop plants through inter-specific hybridization and induction of polyploidy are in progress.

Cytology: Improved cytological techniques for the study of chromosomes during mitosis in root tip cells and in pollen grains have been evolved (Bhaduri & Ghosh, 1954; Bhaduri & Majumdar, 1955). A satisfactory schedule for the study of meiosis in small chromosome plants has also been worked out (Swaminathan *et al.* 1954). With the help of these techniques, karyotype studies have been conducted in several members of the Graminae and some cyto-taxonomic problems have been taken up for investigation. The effects of certain mutagenic chemicals on plant chromosomes are under study.

Genetics: The mode of inheritance of several characters like variegation in rice, chlorophyll deficiency in chilli, linseed and safflower and many mutants in chilli, gram and *Brassica campestris* (*toria*) has been studied.

Information was obtained on the genetics of self-incompatibility in a few diploid *Solanum* species belonging to the section *Tuberarium*, of sex in *Luffa* (Singh *et al.* 1948) and of rust resistance in some varieties of wheat. Work is now in progress to locate genes for rust resistance on particular wheat chromosomes through the use of monosomes. Mutations are being induced in the self-incompatibility alleles of *Brassica campestris* through X-radiation.

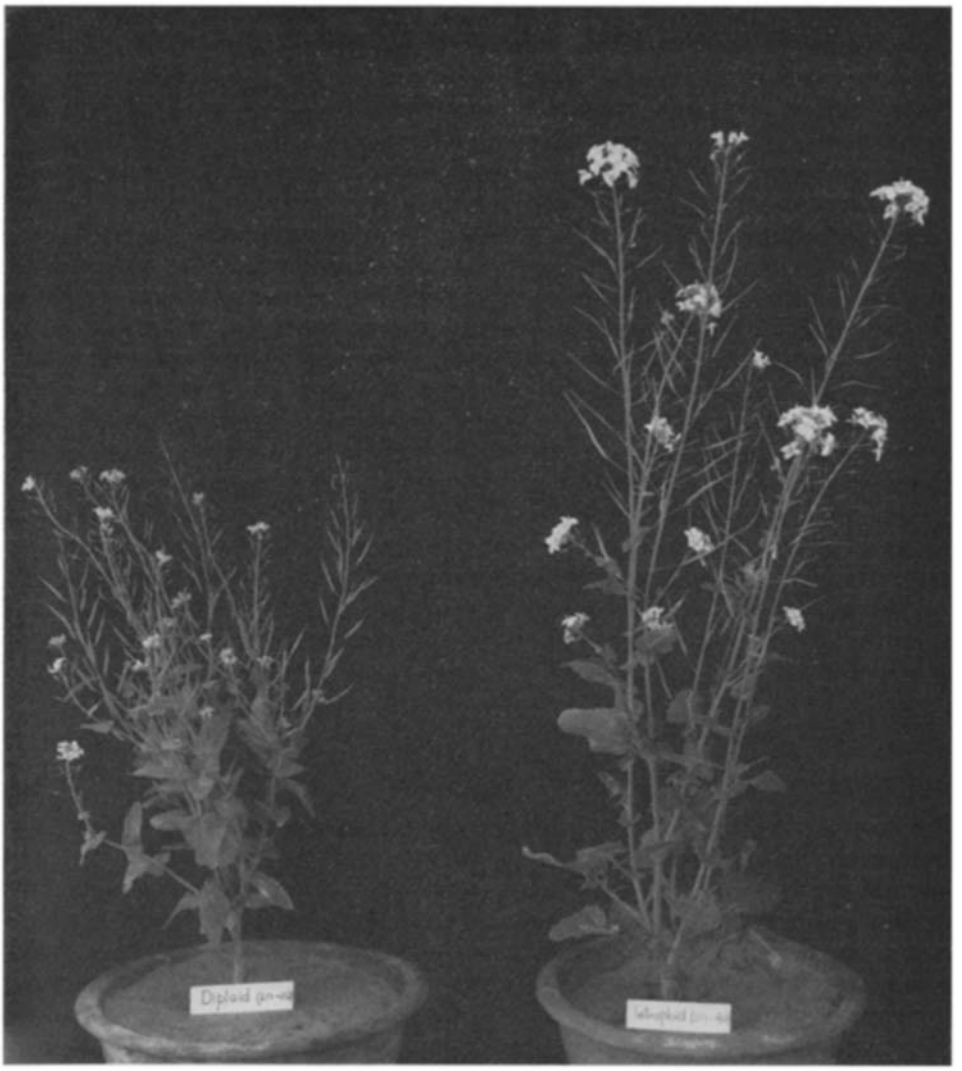

FIG. 4. DIPLOID (LEFT) AND TETRAPLOID (RIGHT). *Brassica Campestris* (*toria*). The tetraploids have shown great promise in yield trials.

Polyploidy: By the colchicine technique, polyploid forms of *Sesame*, gram, chilli, linseed, barley, and *Brassica* (*toria*) have been produced. While all the raw polyploids were disappointing in their yielding ability, highly fertile tetraploid forms of *toria* with increased vigour, longer pods and bolder seed have been obtained by means of the mass pedigree selection method (PARTHASARATHY, 1953; PARTHASARATHY & RAJAN; 1953). It is expected that tetraploid *toria* can be released for general cultivation shortly. Since the diploid and tetraploid plants are cross-incompatible, there is no harm if such populations are grown in adjoining areas. Improvement of several fodder plants is being attempted through the production of polyploid forms.

Amphidiploids were produced from the sterile hybrids of *Nicotiana plumbaginifolia* × *N. glauca*, *Sesamum Orientale* × *S. prostratum*, *Abelmoschus esculentus* × *A. tuberculatus*, *Brassica campestris* × *B. nigra* and several crosses in *Triticinae*. The fertile plants thus obtained have been employed in breeding work.

Species hybridization: Attempts to introduce into the cultivated strains the useful genes from some of the wild relatives, have been made in *bhindi*, *Sesamum*, wheat, potato and tomato. As referred to earlier, some late-blight resistant potato hybrids and an early-ripening tomato variety, Pusa Red Plum, have been evolved in this way.

In *Sesamum*, the cultivated species, *S. Orientale* is usually subject to a bad attack of a caterpillar, *Antigastra catalaunalis*, in the early stages and to the phyllody virus disease which converts the floral organs into leafy structures. A wild species, *S. prostratum*, which grows in the sandy tracts of South India, is resistant to this pest and disease. It was crossed with *S. orientale* and a fertile amphidiploid was produced from the sterile F_1 hybrid (RAMANUJAM, 1944). By back-crossing the amphidiploid with the cultivated varieties, some useful selections combining good yield and resistance, have been obtained.

Species origin: The evolution in nature of *Brassica juncea* through hybridization between *B. campestris* and *B. nigra* followed by chromosome doubling in the sterile hybrid was established by artifically synthesising *B. juncea* – like forms in this way (RAMANUJAM and SRINIVASACHAR, 1943). Much valuable information has also been gathered on the mode of origin of north Indian sugarcanes (PARTHASARATHY, 1951), brinjal (BHADURI, 1951) and *bhindi* (JOSHI and HARDAS, 1953).

6. PHYSIOLOGICAL STUDIES

Extensive physiological investigations have been carried out in wheat with a view to elucidate the correlations between developmental characters of the plant and drought tolerance and immunity from lodging. This work has provided some useful indices and their value in breeding lodging-resistant varieties is now being assessed. By suitably adjusting the intensity of light and temperature, it has been possible to raise three generations of the wheat crop in a year at Delhi. This finding will help to expedite the wheat breeding programme. Studies on the physiological aspects of plant nutrition and utilization of plant hormones both as growth promoters and weedicides are in progress and have already yielded important information. The contribution of leaf and ear components to yield has been estimated in two wheat varieties and it has been found that the relative contributions of these components may vary in different varieties. This result is of significance in the study of the loss in yield caused by the incidence of rust in susceptible varieties (ASANA and MANI, 1949; 1950).

7. POST GRADUATE TRAINING

A two year diploma course can be done at the Institute by advanced students and deputees of Agricultural Departments from the various states of India. At the Division of Botany, specialized training is imparted in the fields of Plant Breeding, Cytogenetics, Plant Physiology and Systematic Botany. During the first year of the course, there are regular lectures and practical classes and during the second year, the student under-

takes work on a research problem and submits a dissertation embodying the results obtained. So far 169 students have taken their diploma from the Botany Division and many of them occupy important positions at the crop breeding institutions in different parts of India.

8. Publications

Besides numerous popular articles of interest to the farming community, about 400 technical papers have been published in periodicals all over the world giving the results of the botanical research carried out at the Institute.

9. Future outlook

On the eve of the Golden Jubilee of the Institute, the work at the Division of Botany is undergoing further expansion. Additional crops like Cotton, *Jowar* (*Sorghum vulgare*) and *Bajra* (*Pennisetum typhoides*) are being included in the intensive breeding programme. A wing for fundamental genetical studies is in the process of organization. Studies in crop physiology and cytogenetics employing the use of radio-active isotopes will be taken up. Provision is also being made for training an increased number of post-graduate students to meet the growing requirements of qualified personnel to implement the agricultural development schemes formulated under the Five Year Plan. It is hence hoped that the Division will continue to make useful contributions to the cause of Indian Agriculture.

10. Summary

The lines of work pursued and some of the results achieved in the field of crop improvement through botanical research at the Indian Agricultural Research Institute, which is celebrating its Golden Jubilee this year, have been mentioned.

11. Samenvatting

Vijftig jaren plantkundig onderzoek aan het Indian Agricultural Research Institute

Schrijvers geven een overzicht van de resultaten op het gebied van de plantenveredeling, welke bereikt zijn door de afdeling botanisch onderzoek van het Indian Agricultural Research Institute, dat dit jaar zijn gouden jubileum herdenkt.

12. References

Asana, R. D. and Mani, V. S., Photosynthesis in the ears of five varieties of wheat. Nature, Lond., **163** (1949): 451.

Asana, R. D. and Mani, V. S., Studies in physiological analysis of yield. I. Varietal differences in photosynthesis in the leaf, stem and ear of wheat. Physiologia Plantarum **3** (1950): 22–39.

Bhaduri, P. N., Inter-relationship of non-tuberiferous species of *Solanum* with some consideration on the origin of brinjal (*S. melongena* L.). Ind. J. Genet. & Pl. Breed. **11** (1951): 75–82.

Bhaduri, P. N., and Ghosh, P. N., Chromosome squashes in cereals. St. Tech. **29** (1954): 269–276.

Bhaduri, P. N., and Mazumdar, B. R., A technique for the study of chromosomes in pollen grains. St. Tech. 30 (1955): 93–98.

CHATTERJEE, D., Note on the origin and distribution of wild and cultivated rices. Ind. J. Genet., & Pl. Breed. **11** (1951): 18–22.

DESHPANDE, R. B., and JESWANI, L. M., A note on the results of performance tests of N.P. rust resistant strains of linseed in the different states of India. Ind. J. Genet. & Pl. Breed. **14** (1954): 22–36.

JOSHI, A. B. and HARDAS, M. W., Chromosome number of *Abelmoschus tuberculatus* Pal et Singh – a species related to the cultivated *bhindi*. Curr. Sci. **22** (1953): 384–385.

PAL, B. P., The Pusa wheats. The wheat breeding work of the Imperial Agricultural Research Institute. Emp. J. Expt. Agr. **12** (1944): 61–73.

PAL, B. P., The control of wheat rusts by breeding. J. Ind. Bot. Soc., **27** (1948): 169–184.

PAL, B. P., The improvement of wheat in India. Proc. **41**st Ind. Science Congress (1954). Part II: 154–181.

PAL, B. P. and PUSHKARNATH, Potato breeding investigations in India. Emp. J. Exp. Agric. **19** (1951a): 87–103.

PAL, B. P. and PUSHKARNATH, Indian Potato varieties. I.C.A.R. Bulletin No **62** (1951b): 63 pp.

PAL, B. P. and RAMANUJAM, S., Plant breeding and genetics at Imperial Agricultural Research Institute, New Delhi, Ind. J. Genet. & Pl. Breed. **4** (1944): 43–53.

PAL, B. P., SINGH, H. B. and SWARUP, V., Taxonomic relationships and breeding possibilities of species of *Abelmoschus* related to okra (A. *esculentus*). Bot. Gaz., **113** (1952): 455–464.

PARTHASARATHY, N., Some cytogenetical aspects of the origin of sugarcane. Ind. J. Genet. & Pl. Breed, **11** (1951): 63–66.

PARTHASARATHY, N., The use of induced polyploids in plant breeding. Ind. J. Genet. & Pl. Breeding **13** (1953): 1–6.

PARTHASARATHY, N., and RAJAN, S. S., Studies on the fertility of autotetraploids of *Brassica campestris* var. *toria*. Euphytica **2** (1953): 25–36.

RAMANUJAM, S., The cytogenetics of an amphidiploid *Sesamum orientale* × *S. prostratum*. Curr. Sci. **13** (1944): 40–41.

RAMANUJAM, S. and JOSHI, A. B., Interspecific hybridisation in *Nicotiana*. A cytogenetical study of the hybrid *N. glauca* × *N. plumbaginifolia*. Ind. J. Genet. & Pl. Breed. **2** (1942): 80–97.

RAMANUJAM, S. and SRINIVASACHAR, D., Cytogenetic investigations in the genus *Brassica* and the artificial synthesis of *B. Juncea*. Ind. J. Genet. & Pl. Breed. **3** (1943): 73–88.

SINGH, H. B., RAMANUJAM, S. and PAL, B. P., Inheritance of sex forms in *Luffa*. Nature, Lond., **161** (1948): 775–76.

SWAMINATHAN, M. S., MAGOON, M. L. and MEHRA, K. L., A simple propiono-carmine PMC smear method. Ind. J. Genet. & Pl. Breed. **14** (1954): 86–87.

VENKATARAMAN, T. S., Hybridization in and with the genus *Saccharum* (its scientific and economic aspects). Proc. **25**th Indian Sci. Congr. Calcutta, Part II: 267–284.