IISc Centenary Lecture Series

M S Swaminathan

Science and Sustainable Food Security

Selected Papers of M S Swaminathan

IISc Press
World Scientific

IISc Centenary Lecture Series

Science and Sustainable Food Security

Selected Papers of M S Swaminathan

M S Swaminathan
M S Swaminathan Research Foundation, India

IISc Press

World Scientific

NEW JERSEY • LONDON • SINGAPORE • BEIJING • SHANGHAI • HONG KONG • TAIPEI • CHENNAI

Published by

World Scientific Publishing Co. Pte. Ltd.
5 Toh Tuck Link, Singapore 596224
USA office: 27 Warren Street, Suite 401-402, Hackensack, NJ 07601
UK office: 57 Shelton Street, Covent Garden, London WC2H 9HE

British Library Cataloguing-in-Publication Data
A catalogue record for this book is available from the British Library.

IISc Centenary Lecture Series — Vol. 3
SCIENCE AND SUSTAINABLE FOOD SECURITY
Selected Papers of M S Swaminathan

ISBN-13 978-981-4282-10-9
ISBN-10 981-4282-10-3

Editor: Tjan Kwang Wei

Printed in Singapore by B & Jo Enterprise Pte Ltd

Science and Sustainable Food Security

Selected Papers of M S Swaminathan

Norman Borlaug
1914–2009

Dedicated to
Dr Norman E Borlaug for his unparalleled contributions to shaping our agricultural destiny and to saving millions of lives from hunger and famine.

ACKNOWLEDGEMENTS

I express deep sense of gratitude to the various publishers for giving copyright permission to reproduce the following articles in the book:

Taylor & Francis Group: Articles (1) Swaminathan, M.S. (1983). Agricultural Progress-key to third world prosperity. Third World Quarterly 5(3):553- 566. and (2) Swaminathan, M. S. 2003. Sustainable Food Security in Africa: Lessons from India's Green Revolution. South African Journal of International Affairs. 10(1): 11-26

Nature: Articles (1) Swaminathan, M.S. (1955). Overcoming cross-incompatibility among some Mexican diploid species of ***Solanum***. Nature 176:887-888 (2) Swaminathan, M.S. and A.T. Natarajan (1957). Polyploidy and radiosensitivity. Nature 179:479-480 and (3) Swaminathan, M.S. (1956). Disomic and tetrosomic inheritance in a ***Solanum*** hybrid. Nature 178:599-600.

Elsevier: Sanchez Pedro, A and Swaminathan M S (2005). Hunger in Africa : the link between unhealthy people and unhealthy soils. The Lancet – Vol. 265, Issue 9457, 29 January 2005, 442-444 Pp.

In addition, there are a number of articles in this book that do not require formal copyright permissions but at the same time I am thankful to these Publishers and the Journals for the rewarding association that I had with them over several decades. They are: The Little Magazine, Consultative Group on International Agricultural Research, TWAS Newsletter, Science, Field Crops Research, Cambridge University Press, Ankuram, Jawaharlal Nehru Memorial Lecture Organization, Current Science, Wheat Information Service, Springer, Wiley, Genetics, Australian National University Press, United Nations, Institute of Biology, World Meteorological Organisation. The Royal Society, Oxford & IBH Publishing Company, and The Hindu.

I also wish to thank Dr N Parasuraman for his painstaking efforts in getting all the papers assembled for this publication.

M S Swaminathan

Foreword

The Indian Institute of Science is one of India's oldest research institutions. In commemorating a century of existence a program of Centenary Lectures was initiated in 2008. These lectures were intended to bring scientists of the highest accomplishment to the Institute to inform and inspire a new generation of researchers. For Indians who have lived through the decades of the 1960s and 1970s two images are etched in memory. The first is the spectre of food shortages and rationing, which impacted almost all sections of the population. The second is the remarkable transformation that took place in the 1970s, when the Green Revolution took root, quickly consigning the era of large scale food imports to the realm of history. Prof. M.S. Swaminathan is one of the acknowledged architects of this agricultural revolution; a transformation that required the happy confluence of political will, administrative efficiency, scientific input and the enthusiastic acceptance by farmers of new crop varieties. Over three decades later India stands on the threshold of a new and looming crisis in agriculture which Prof. Swaminathan articulates so clearly: "We should look upon agriculture not just as a food-producing machine for the urban population, but as the major source of skilled and remunerative employment and the backbone of the rural livelihood system". This volume is intended to focus attention on these important issues, conveying a sense of urgency on the need to catalyze a second transformation in Indian agriculture in this new century.

P. Balaram
Director
Indian Institute of Science Bangalore
India

About Prof M.S. Swaminathan

Professor M S Swaminathan has been acclaimed by the TIME magazine as one of the twenty most influential Asians of the 20th century and one of the only three from India, the other two being Mahatma Gandhi and Rabindranath Tagore. He has been described by the United Nations Environment Programme as "the Father of Economic Ecology" because of his leadership of the ever-green revolution movement in agriculture and by Javier Perez de Cuellar, Secretary General of the United Nations, as "a living legend who will go into the annals of history as a world scientist of rare distinction". He was Chairman of the UN Science Advisory Committee set up in 1980 to take follow-up action on the Vienna Plan of Action. He has also served as Independent Chairman of the FAO Council (1981–85) and President of the International Union for the Conservation of Nature and Natural Resources (1984–90). He was President of the World Wide Fund for Nature (India) from 1989–96. He also served as President of the Pugwash Conferences on Science and World Affairs (2002–07), President of the National Academy of Agricultural Sciences (1991–96 and 2005–07) and Chairman, National Commission on Farmers (2004–06).

He served as Director of the Indian Agricultural Research Institute (1961–72), Director General of Indian Council of Agricultural Research and Secretary to the Government of India, Department of Agricultural Research and Education (1972–79), Principal Secretary, Ministry of Agriculture (1979–80), Acting Deputy Chairman and later Member (Science and Agriculture), Planning Commission (1980–82) and Director General, International Rice Research Institute, the Philippines (1982–88).

A plant geneticist by training, Professor Swaminathan's contributions to the agricultural renaissance of India have led to his being widely referred to as the scientific leader of the green revolution movement. His advocacy of sustainable agriculture leading to an ever-green revolution makes him an acknowledged world leader in the field of sustainable food security. The International Association of Women and Development conferred on him the first international award for significant contributions to promoting the knowledge, skill, and technological empowerment of women in agriculture and for his pioneering role in mainstreaming gender considerations in agriculture and rural development. Professor Swaminathan was awarded the Ramon Magsaysay Award for Community Leadership in 1971, the Albert Einstein World Science Award in 1986, the first World Food Prize in 1987, and Volvo and Tyler Prize for Environment, the Indira Gandhi Prize for Peace, Disarmament and Development in 2000 and the Franklin D Roosevelt Four Freedoms Medal, the Mahatma Gandhi Prize of UNESCO in 2000 and the Lal Bahadur Sastri National Award (2007).

Professor Swaminathan is a Fellow of many of the leading scientific academies of India and the world, including the Royal Society of London and the U S National Academy of Sciences. He has received 59 honorary doctorate degrees from universities around the world. He currently holds the UNESCO Chair in Ecotechnology at the M S Swaminathan Research Foundation in Chennai (Madras), India. He is a Member of the Parliament of India (Rajya Sabha), to which position he was nominated by the Government of India in May 2007 in recognition of his contributions in the field of agricultural research and development.

Contents

Dedication v

Acknowledgment vii

Foreword ix

About the Editor xi

Introduction 1

Section I: Food Security and Economic Development — *How science is applied to solve problems of poverty, drought and famine*

Commentary

1. Swaminathan, M.S. (1983). Agricultural Progress — Key to Third World Prosperity. *Third World Quarterly* **5**(3): 553–566. 27

2. Swaminathan, M.S. (1990). Changing Nature of the Food Security Challenge: Implications for Agricultural Research and Policy. *Sir John Crawford Memorial Lecture (Consultative Group on International Agricultural Research (CGIAR)*, Washington DC. 41

3. Swaminathan, M.S. (2001). Bridging the Nutritional Divide — Building Community Centred Nutrition Security Systems. *The Little Magazine*, Year end, 2001, pp. 15–25. 67

4. Swaminathan, M.S. (2004). Africa's Rainbow Revolution. *TWAS Newsletter 3/4*, **10**, 72–76. 79

5. Sanchez Pedro, A. and Swaminathan, M.S. (2005). Hunger in Africa: The Link Between Unhealthy People and Unhealthy Soils. *The Lancet* — Vol. **265**, Issue 9457, 29 January 2005, 442–444. 85

6. Sanchez Pedro, A. and Swaminathan, M.S. (2005). Cutting World Hunger in Half. *Science* **307**(5708): 357–359. 89

7. Swaminathan, M.S. (2007). Can Science and Technology Feed the World in 2025? *Field Crops Research* **104**: 3–9. 93

8. Parry, Martin L. and Swaminathan, M.S. (1992). Effects of Climate Change on Food Production. *Confronting Climate Change: Risks, Implications and Responses*. Irwing, M, Montzer (ed.) Cambridge University Press, pp. 113–115. 107

9. Swaminathan, M.S. (2003). Sustainable Food Security in Africa: Lessons from India's Green Revolution. *South African Journal of International Affairs* **10**(1): 11–26. 133

10. Swaminathan, M.S. (2003). Sustainable Food and Water Security. *Ankuram – Environment Quarterly* **1**(1): 23–33. 147

Section II: Science and Food Security — *How science is used to generate efficient and optimal agricultural outputs*

Commentary

11. Swaminathan, M.S. (1999). Science and Sustainable Food Security. *31st Jawaharlal Nehru Memorial Lecture*, New Delhi, 39 pp. 185

12. Swaminathan, M.S. (1981). Indian Agriculture at the Crossroads. *Current Science* **51**: 13–24. 225

13. Bui Ba Bong and Swaminathan, M.S. (1995). Magnitude of Hybrid Vigor Retained in Double Haploid Lines of Some Heterotic Rice Hybrids. *Theor. Appl. Genet.* **90**: 253–257. 237

14. Swaminathan, M.S., Chopra, V.L., Joshi B.C. and Singh, D. (1968). Development of Monosomic Series in an Indian Wheat and Isolation of a Nullisomic Lines. *Wheat Information Service* **27**: 19–20. 243

15. Kumar, S., Pai, R.A. and Swaminathan, M.S. (1967). Consanguineous Marriages and the Genetic Load Due to Lethal Genes in Kerala. *Ann. Hum. Genet. Lond.* **131**: 141–147. 245

16. Swaminathan, M.S. (1965). The Experimental Manipulation of Genes. *Curr. Sci.* **34**: 108–111. 253

17. Swaminathan, M.S. (1954). Nature of Polyploidy in Some 48-Chromosome Species of the Section ***Tuberarium*** Genus ***Solanum***. *Genetics* **39**: 56–76. 257

18. Swaminathan, M.S. (1955). Overcoming Cross-Incompatibility Among some Mexican Diploid Species of ***Solanum***. *Nature* **176**: 887–888. 275

19. Swaminathan, M.S. and Natarajan, A.T. (1957). Polyploidy and Radiosensitivity. *Nature* **179**: 479–480. 277

20. Swaminathan, M.S. (1956). Disomic and Tetrosomic Inheritance in a ***Solanum*** Hybrid. *Nature* **178**: 599–600. 279

21. Swaminathan, M.S. (1992). The Green Revolution in Indian Agriculture From an Environmentally Sound Technology Point of View. *Environmentally sound technology for sustainable development. Advanced Technology Assesment System Bulletin (7)*. Dirk Pilari and David Philips Eade (eds.). United Nations Publication, New York, pp. 143–148. 281

22. Swaminathan, M.S. (2006). Science and Shaping Our Agricultural Future. *The First Ten K. R. Narayanan Orations: Essays by Eminent Persons on the Rapidly Transforming Indian Economy*. Raghbendra Jha (ed.). The Australian National University Press, Canberra, pp. 155–183. 293

Section III: Food Security and Ecological Balance — *How the gains of green revolution are impacted by climate change, how science will be helpful in ensuring sustainable food security, green revolution to ever-green revolution — a roadmap*

Commentary

23. Swaminathan, M.S. (2000). An Evergreen Revolution, *Biologist* **47**(2): 85–89. 325

24. Swaminathan, M.S. (1990). Agriculture and Food Systems. *Proceedings of the Second World Climate Conference, Geneva, World Meteorological Organisation.* 331

25. Kesavan, P.C. and Swaminathan M.S. (2006). Managing Extreme Natural Disasters in Coastal Areas. *Philosophical Transactions of The Royal Society*, pp. 2191–2216. 345

26. Swaminathan, M.S. (1999). Ecological Security — A Prerequisite for Food and Livelihood Security. Ahmad K. Hegazy (ed.). *Environment 2000 and Beyond.* International Center for Environment and Development, Cairo, Egypt, pp. 203–222. 367

27. Swaminathan, M.S. (1984). Genetic Conservation: Microbes to Man. Presidential Address, *XV International Congress on Genetics. Genetics: New Frontiers*, Vol. 1. Oxford & IBH Publishing Co., New Delhi, pp. 29–56. 387

28. Monsoon Management in an Era of Climate Change. 417

From Green to an Ever-green Revolution

M.S. Swaminathan

The rediscovery of Mendel's laws of inheritance in 1900 helped plant breeders to initiate scientifically designed efforts to develop new varieties of crops based on the principles of genetic segregation, recombination and mutation. Genetic selection has however been in progress almost from the beginning of agriculture or settled cultivation over 10,000 years ago. This explains the basis for the occurrence of a rich diversity of land races or locally adapted strains of both plants and farm animals. Genetics however helped to undertake carefully planned hybridization and selection experiments. From 1930 onwards, mutation breeding using ionizing radiations also became feasible, thanks to the discovery by H J Muller and L J Stadler that exposure of animals and plants to X-rays and other radiations can result in the induction of mutations.

From the early years of agriculture, increasing crop productivity and resistance to pests and diseases have been major goals of farm families. The discovery of mineral fertilizers in the later part of the 19th century by Liepzig and other German scientists helped to halt the law of diminishing return of the soil. Genetic resistance, crop rotations and chemical and biological pesticides helped to minimize crop losses due to pest epidemics. Inspite of such progress, famines were frequent in the past due to crop failure caused by both pest epidemics and adverse meteorological conditions. Even today, the saying that "Indian agriculture is a gamble in the monsoon" has some validity.

The rediscovery of Mendel's laws of inheritance almost coincided with the establishment in 1905 of the Indian (then Imperial) Agricultural Research Institute at Pusa, Bihar, and the Agricultural Colleges at Coimbatore, Nagpur, Pune, Kanpur and Lyalpur (now Faizalabad in Pakistan). At all these centres, research, education and extension education were integrated in order to help achieve a technological upgrading of traditional farming practices. The early breeding method was selection among naturally occurring variability. This led to wheat varieties like NP4 developed by Sir Albert and Gabrielle Howard at Pusa and rice varieties like GEB 24 bred by Dr K Ramaiah at Coimbatore.

The early breeding work centred around the development of crop varieties with resistance to pests and diseases, adaptation to local growing conditions and good culinary and organoleptic properties. Often dual purpose varieties were selected – good grain quality for human consumption and good straw quality for the consumption of ruminating farm animals. In wheat, varieties like NP809 possessing resistance to stem, leaf and stripe rusts were developed at IARI by a team led by Dr B P Pal.

After independence in 1947, increase in human population occurred at an accelerated pace, thanks to advances in preventive and curative medicine. Also, India's independence was born in the backdrop of the Bengal Famine of 1942-43, which resulted in the death of over 2 million children, women and men. Thus led Jawaharlal Nehru, the first Prime Minister of India, to observe in 1947, "everything else can wait but not agriculture". The Nehru era (1947-1964) was marked by infrastructure development for scientific agriculture, such as irrigation projects, fertilizer factories, Agricultural Universities and research institutes and extension agencies. Inspite of all these efforts, food production could not keep pace with population increase, with the result that the country started depending upon imported food, particularly wheat under the PL480 programme of the United States of America. As much as 10 million tonnes of wheat were imported in 1966. Indians were thus reduced to a "ship to mouth" existence.

It is in this background that the Government of India introduced in 1961 an Intensive Agricultural District Programme (IADP) in order to maximize the benefits of assured irrigation facilities, by providing farmers a package of inputs like seeds, fertilizers and extension advice. Early results from IADP were disappointing in relation to the enhancement of productivity per hectare. Advances in production were largely due to an increase in area rather than in yield, ie, a horizontal expansion in cultivated area and not a vertical expansion in productivity. It was observed that traditional wheat and rice varieties, if fed with mineral fertilizers, tended to lodge because of their tall height and thin straw. Since wheat and rice plants need about 25 and 20 kgs of Nitrogen respectively to yield one tonne of grain, it became clear that unless the architecture of the plant can be redesigned in order to enable them to utilize higher quantities of nutrients and irrigation water, low yields will continue to prevail.

My first assignment on my return from foreign studies early in 1954 was in the *Indica-Japonica* hybridization programme in rice at the Central Rice Research Institute at Cuttack. The aim of this programme which was a brain child of Dr K Ramaiah was to transfer genes for fertilizer response from *japonica* to *indica* rice varieties. The *indica* varieties cultivated then had tall straw and will lodge if the quantity of mineral fertilizers essential for raising the yield level from 1 to 4 tonnes of rice, was applied. The *indica-japonica* hybridization programme resulted in a few good varieties like ADT-27 in Tamil Nadu and Mashuri in Malaysia. However, real progress in yield improvement had to await the introduction of semi-dwarf *indica* varieties, based on the Dee-gee-woo-gen dwarfing gene identified in China and used in Taiwan to develop varieties like Taichung Native 1. Later, this gene was used at the International Rice Research Institute (IRRI) at Los Banos, the Phillipines, leading to the breeding of the high yielding variety, IR8 in 1968.

I joined the Indian Agricultural Research Institute (IARI), New Delhi in late 1954. IARI, which was originally located at Pusa in Bihar, was shifted to New Delhi in 1936, following the damage caused to its original laboratories at Pusa by the Bihar earthquake of 1934. My first aim, on joining IARI, was to repeat the efforts in rice, namely the breeding of high yielding varieties which can take advantage of good soil fertility management and irrigation water availability. A three pronged strategy was developed for this purpose.

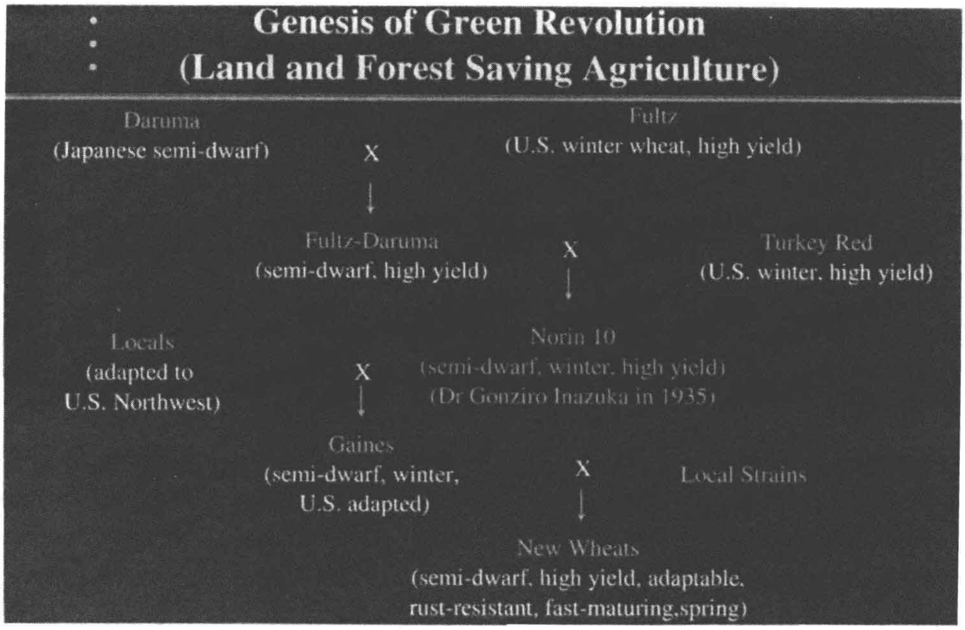
- First, efforts were made to develop **erectoides** mutants on the lines of the work done in barley in Sweden by a team led by Prof Ake Gustafson. X-rays, gamma rays and fast and thermal neutrons, as well as chemical mutagens like ethyl-methane-sulphonate were used for this purpose. A Gamma Garden using a 200 Curie Cobalt 60 source was also set up at IARI for subjecting plants to chronic doses of gamma radiation.

- Secondly, a search was made for naturally occurring dwarf wheat species and varieties like *Triticun aestivum* sub.sp *sphaerococcum* (popularly known as Mohanjadaro wheat, since its Kernels were identified in the Mohanjadaro excavation). *T. aestivum sub.sp compactum* and Tom Thumb. They were crossed with wheat varieties from IARI as well as Punjab (eg. C591, C306 etc bred by Chaudhary Ram Dhan Singh).
- Thirdly, attempts were made to induce chemical dwarfing by spraying maleic hydrazine.

Unfortunately, all these pathways of breeding fertilizer responsive, semi-dwarf wheat varieties did not succeed, since the dwarf height was associated with a short panicle with a low grain number and grain weight. Thus the dwarf plant habit had a pleiotropic effect on the panicle and thereby on yield.

It is in this background, I was attracted to the work of Dr Orville Vogel of the Washington State University, Pulman, USA when he announced the release of the winter wheat variety Gaines, capable of yielding over 10 tonnes per ha, based on the Norin dwarfing gene identified by Dr Gonziro Inazuka at the Norin Experiment Station in Japan (Fig. 1). I wrote to Dr Vogel in 1960 requesting seeds of Gaines. While sending the seeds, he also mentioned that winter wheats, which required long days and mild temperature to flower and set grain, will not do well under the short day conditions prevailing during the *rabi* season (November to April) in North India. He suggested that I should obtain seeds of spring wheat varieties with the same dwarfing gene from Dr Norman E Borlaug, who was developing semi-dwarf varieties under a Rockefeller Foundation – Mexican Government programme in Mexico using the Norin dwarfing genes made available to him by Dr Vogel. Meanwhile, I and my colleague, Dr M V Rao, observed during 1960-61 semi-dwarf wheat varieties with long panicles and high yield potential in the International Wheat Rust Nursery sent by the US Department of Agriculture as part of an international programme to map the wheat rust profile in different countries and to identify genes for resistance to the dominant races of leaf, stripe and stem rusts. On enquiring from USDA, the semi-dwarf, long panicle entries were traced to the wheat breeding programme of Dr Norman Borlaug in Mexico. I then wrote to Dr Borlaug requesting seeds of a wide range of semi-dwarf material. He promptly replied saying that he will be happy to provide the material but it will help him to select material for being sent to India, if he visits the wheat growing areas of India. Early in 1961, I wrote to Dr B P Pal then Director of IARI, requesting him to extend an invitation to Dr Borlaug to visit India. It took over a year for the Ministry of Agriculture to send a letter of invitation to Dr Borlaug through the Rockefeller Foundation (then headed in India by Dr Ralph W Cummings). Finally Dr Borlaug visited us in March 1963.

Figure 1



During March 1963, I and some of my colleagues took Dr Borlaug to the major wheat growing regions of the country. It was a wonderful experience traveling with him since I found him to be not only a brilliant scientist, but a humanitarian to the core. In an article in Yojana (published by the Planning Commission in 1965) I referred to Dr Borlaug as the Albert Schweitzer of Agriculture and I was happy that like Schweitzer, he also received the Nobel Peace Prize in 1970.

On the conclusion of his visit towards the end of March 1963, Dr Borlaug mentioned that since most of his semi-dwarf wheat material was growing in Pakistan – Punjab, he would like to observe their behaviour before selecting strains to be sent to India. He therefore went in late March 1963, from Delhi to Lahore and spent a week in Pakistan studying the performance of the Mexican wheat material he had sent there under a FAO supported Cereal Improvement Programme. In May, 1963, he wrote to me an ecstatic letter saying that several of the Mexican semi-dwarf strains are performing very well in Pakistan. I requested him to send, in addition to segregating populations, atleast 100 kgs of seeds of 4 semi-dwarf varieties released in Mexico, namely Sonora 63, Sonora 64, Majo 64, and Lerma Rojo 64-A. He was good enough to send in September 1963, bulk quantities of seeds of these varieties, in addition to a wide range of segregating material. A five year plan (1963-68) was developed to prepare a road map for the Wheat Revolution.

To purchase time, I decided to divide the seeds received into several lots, so that we can get data simultaneously from Delhi, Ludhiana, Pant Nagar, Kanpur and Pusa during the *rabi* season of 1963-64. This helped us to study the genotype X environment interaction. I summarized this data at the All India Wheat Workshop held at IARI in August 1964 (Swaminathan MS 1965, "The Impact of Dwarfing Genes on Wheat Production" Journal of the IARI Post-graduate School, 1965, Vol.2, pp 57-62). It was clear that with the semi-dwarf varieties we can atleast treble the yield immediately (the average yield of wheat at that time was less than 1 tonne per ha). In addition, the semi-dwarf wheat strains from Mexico showed wide adaptation to diverse growing conditions, since Dr Borlaug had introduced the character of photo-insensitivity through shuttle breeding. I therefore proposed that a National Demonstration Programme may be initiated in small farmers' fields during *rabi* 1964-65, in order to serve as windows into the world of high wheat yield awaiting our farmers (Swaminathan, M.S. 1966. National Demonstrations in Rice. Indian Farming 16(6):67-70). *I had stipulated in my proposal that the demonstrations should be laid in the fields of small farmers since yield results from demonstrations in rich farmers' fields will be attributed to affluence and not to technology*. There were objections to this approach from the Ministry of Agriculture, since according to them, demonstrations should be laid out in the fields of "progressive farmers", an euphemism for resource–rich farmers. Fortunately, Bharat Ratna C Subramaniam, who had then joined as Union Minister of Food and Agriculture, overruled this objection and approved my proposal for organizing National Demonstrations in the fields of resource poor farmers. Seeds and fertilizers were provided to farmers under this programme but all the cultivation work was done by the farm family. The small farmers chosen under this programme adopted the right agronomic practices and harvested on an average over 4 tonnes per ha during April 1965. This revolutionary change in yield stirred up great enthusiasm among wheat farmers and there was a huge demand for seeds of the semi-dwarf wheat varieties. The Government of India approved in April 1966, our proposal to import 18,000 tonnes of seeds of Lerma Rojo 64A and Sonora 64 from Mexico. These seeds arrived on time for *rabi* sowing in September 1966 and were distributed among all major wheat growing states. At the same time, a Seed Village programme was started in the Jounti Village in Delhi State, where all farmers agreed to multiply the seeds of the semi-dwarf wheat varieties (Swaminathan, M S, 1968. The Evolution and Significance of Jounti Seed Village. Indian Farming. Jan 1-4). As a result of this *"purchase time operation"* nearly a million ha came under semi-dwarf varieties in the rabi season of 1967-68, resulting in an increase of nearly 7 million tonnes in wheat production in April 1968. Meanwhile, we also developed semi-dwarf varieties with amber grains and good chapathi making qualities from the segregating material received from Dr Borlaug, such as Kalyan Sona and Sonalika.

In February, 1968, Smt Indira Gandhi came to IARI for delivering the Convocation Address. I then mentioned in my welcome address that the wheat harvest of 1968 will mark the beginning of a new era in Indian agriculture. I requested her to release a special stamp to bring this significant event in India's agricultural history to the attention of the public. She approved this proposal and a special stamp titled "the Wheat Revolution" was released by her in July 1968 at the IARI Auditorium. The details of the scientific and developmental efforts which led to the Wheat Revolution are chronicled in a Monograph titled "Wheat Revolution: a Dialogue" (Swaminathan, M.S. (Ed.) 1993. *Wheat Revolution: A dialogue*. Macmillan India Ltd., Madras 164pp).