# Advances in Genetic Enhancement of Early and Extra-Early Maize for Sub-Saharan Africa

Baffour Badu-Apraku • M.A.B. Fakorede

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Springer

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ISBN 978-3-319-64851-4 ISBN 978-3-319-64852-1 (eBook)
DOI 10.1007/978-3-319-64852-1

Library of Congress Control Number: 2017953537

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Printed on acid-free paper

This Springer imprint is published by Springer Nature
The registered company is Springer International Publishing AG
The registered company address is: Gewerbestrasse 11, 6330 Cham, Switzerland

# Foreword

About 300 million people of sub-Saharan Africa (SSA) depend on maize as a staple food. During the last three decades, there have been tremendous strides in increasing maize production and productivity in the region due to the development of early, extra-early, intermediate-, and late-maturing maize varieties with improved resistance to *Striga hermonthica*, the maize streak virus (MSV), downy mildew, and stem borers along with tolerance to drought for the forest, forest–savanna transition, and savanna agroecological zones. Reviewed in this book are the breeding methodologies and strategies that have been adopted for the improvement of the early and extra-early varieties that have largely contributed to the phenomenal increases in maize production and productivity in the savannas, especially the northern fringes of the Guinea savanna and the Sudan savannas.

Even though there are many books on the principles and practices of maize breeding and improvement, the major focus of these books has been on temperate maize. This book focuses on the principles and practices of maize improvement of tropical maize with special emphasis on early and extra-early maize. This book should therefore be of great interest to maize breeders, graduate students, and professors of maize breeding interested in the genetic enhancement of maize to feed the increasing population of sub-Saharan Africa. The book should also be useful to national agricultural research and extension systems, nongovernmental organizations (NGOs), seed companies, community-based seed organizations, and policymakers interested in generating wealth from agriculture and providing agricultural solutions to alleviate hunger and poverty in the sub-region.

The material in this book is based on the wealth of knowledge accumulated during the last three decades in breeding early and extra-early maize for tolerance/resistance to biotic and abiotic stresses in SSA and the experience gained over the years in offering training courses in maize improvement and seed production to young scientists and technicians of the sub-region. Thus, this book on maize improvement is unique to the extent that it is based on the practical experience and realities in SSA and is also relevant to the situation and circumstances of the maize breeders and farmers of the sub-region.

Director General, IITA, Ibadan, Nigeria N. Sanginga

# Preface

Maize production in SSA has been greatly constrained by many biotic and abiotic stresses. Most of these constraints cut across countries with similar agroecological zones, the most important being drought, low soil fertility, *Striga* infestation, stem borers, and maize streak virus (MSV). The last two are more important in the more humid southern zones. In addition, farmers face a variety of policy and institutional constraints, such as undeveloped markets, the high cost of farm inputs, high labor requirements for land preparation and weeding, lack of good-quality seed, and difficult access to credit, all of which inhibit increases in maize yields and production. Improved maize varieties grown under controlled and well-managed conditions on research stations can produce average yields of 4–5 t/ha in the forest zone and 5–8 t/ha in the savanna zones, but the average yield in the farmers' fields is currently about 1.5 t/ha, one of the lowest in the developing world. National maize scientists of West and Central Africa (WCA), in collaboration with farmers, identified, in 1998, maize production constraints as the need for improved crop varieties, appropriate natural resource and crop management, plant health, postharvest technologies, socioeconomic practices and conditions, as well as the need to improve human capacity. During the last three decades, maize breeders at IITA in collaboration with national scientists of WCA have addressed ecologically specific adaptive traits, including the varietal development of resistance to MSV, *Helminthosporium* leaf blight (*H. maydis*), *Striga* spp., and stem borers, as well as tolerance to drought and low soil nitrogen (N). Also critical was the development of a vibrant seed sector. In spite of the substantial effort in breeding and the large number of new varieties released in WCA since the 1990s, impacts of maize research and development have not been as high as expected, partly due to the nonavailability of good-quality improved seeds for farmers. Public sector production and marketing of seeds have achieved mixed results but have often been limited by inadequate resources and poor management.

The early and extra-early maturing varieties are used for filling the hunger gap in the savannas of SSA, and this has allowed the early and extra-early varieties to spread into the shorter rainfall areas which for a long time had been precluded from maize production. Within the framework of the IITA Maize Improvement Program,

the ultimate goal of the early and extra-early maturing breeding unit has been to improve maize in the two maturity groups for biotic and abiotic stress tolerance. This program, undertaken in collaboration with NARS scientists of WCA, focused on developing breeding materials with resistance/tolerance to the major biotic and abiotic stress factors, including *Striga*, drought/heat stress, low soil N, MSV, rust, and leaf blight, as appropriate in all agroecologies. The program has since inception focused on four strategies for the two maize maturity groups: development of stress-tolerant (*Striga* resistant, drought and low-N tolerant) maize source populations for recurrent selection; improvement of source populations using recurrent selection with reliable artificial field infestation and screening methods to increase resistance to relevant stresses in the breeding materials; extraction of open-pollinated varieties (OPVs), inbred lines, and hybrids from source populations; and germplasm enhancement.

This book reviews the methodologies, strategies, and advances in maize improvement in SSA during the last three decades with special emphasis on the early and extra-early maize. Some aspects of research activities relevant to the intermediate- and late-maturing maize in which substantial progress has been made in improving resistance to downy mildew, stem borers, and aflatoxin-producing fungi by IITA maize breeders during the last three decades have also been reviewed in the book. Despite the tremendous progress made in developing and promoting maize varieties and hybrids, over one-third of the maize area in WCA is still planted with farmer-saved, low-yielding varieties (Arega et al. 2009). At the same time, many farmers continue to use seed saved from their farms because improved varieties are either not accessible to them or they regard improved seed as too costly. Since maize is an open-pollinated crop, farm-saved seed can quickly lose its genetic purity, implying that farmers who wish to grow improved varieties must replace their seed regularly, annually in the case of hybrid varieties and every 2–3 years in the case of OPVs. The development and dissemination of maize varieties and hybrids adapted to the increasingly drought-prone conditions and *Striga* endemic savannas require ongoing support to avert hunger and malnutrition in SSA.

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June 2017

# Acknowledgments

We gratefully acknowledge the financial support of the DTMA/STMA Project since 2007 and USAID from 1987 to 2007 for the research reported in this book. The United Nations Development Programme (UNDP), the International Fund for Agricultural Development (IFAD), and the Nippon Foundation provided additional financial support for the research reported herein from 1998 to 2006 through the Africa Maize Stress (AMS) Project. We express our sincere thanks for the research facilities provided by INERA at the Kamboinse Research Station, Burkina Faso, from 1987 to 1993 and by the Centre National de Recherche Agronomique (CNRA) at Ferkessédougou, Côte d'Ivoire. The cooperation of the director general of INERA and CNRA, heads of stations, and Burkinabe and Ivorian scientists in the respective countries has contributed significantly to the successful execution of the research activities, and for this we are very grateful. We express our appreciation to the AU-SAFGRAD/STRC Coordination Office in Ouagadougou for the administrative support during the period 1987–1993. The Africa Rice Center, Bouake, Côte d'Ivoire, provided space and logistical support for the breeding program on the early and extra-early maize for about 9 years, and we express our appreciation. We acknowledge CIMMYT for providing some of the germplasm used in the early and extra-early maize activities, along with some of the information reported in this book as well as good collaboration. We would also like to thank Drs. Alpha Diallo and J.M. Fajemisin, the first two coordinators of WECAMAN for laying a strong foundation upon which the program was built. The late Dr. M. Quin, former IITA director of the Crop Improvement Program; Dr. J.P. Eckebil, former deputy director general for International Cooperation of IITA; Drs. J.M. Menyonga and T. Bezuneh, international coordinators of OAU/SAFGRAD; Dr. Mahama Ouedraogo of AU/SAFGRAD-STRC; and Mr. F. Deganus have made significant contributions to the success of the activities reviewed in this book, and we acknowledge this. The activities reported in this book were fully supported by the IITA management, particularly Dr. Robert Asiedu, director of the West Africa Hub of IITA, and Dr. Ylva Hillbur, former IITA deputy director general R4D, with their unflinching support over the years, which has contributed significantly to the success of the early and extra-early maize program at IITA. We would like to acknowledge the support of

fellow IITA, DTMA/STMA Project, and national maize scientists of West and Central Africa (WCA), particularly Drs. A. Menkir, T. Abate, S.O. Ajala, T. Abdoulaye, K. Obeng-Antwi, J. Onyibe, C. Yallou, A. Kamara, S.K. Kim, and N'Tji Coulibaly for their collaboration and immense contribution to the success of the research on early and extra-early maize. We are grateful to all the support staff of the IITA Maize Improvement Program (MIP), especially Messers A. Talabi, B. Annor, and M. Aderounmu, as well as the former support staff including Drs. M. Oyekunle and R. Akinwale and Mr. S. Makinde for their hardwork, amiable commitment, and unflinching support. Our Ph.D. students, S. Adewale, C. Nelimor, E. Obeng-Bio, T. Noudiloule, O. Ayanniyi, and O. Toyinbo, assisted with the editing and proofreading of some specific chapters for which we are very grateful. Finally, we would like to express our sincere thanks to Professor J.G. Kling of Oregon State University, USA; Professors A.O. Salami, O.K. Adekunle, and A.S. Bamire and Drs. B.O. Odu, Dr. A. Akinola, and O.J. Soyelu, all of Obafemi Awolowo University, Ile-Ife, Nigeria; and Dr. Togola and Alejandro Ortega-Beltran, both of IITA, as well as Dr. Francis Nweleni of Africa Rice, Ibadan, Nigeria, for the critical and constructive review of some chapters of the book.

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# Abbreviations and Acronyms

| | |
|---|---|
| AMMI | Additive main effect and multiplicative interaction |
| ANOVA | Analysis of variance |
| ASI | Anthesis–silking interval |
| GGE | Genotype–genotype environment |
| CGIAR | Consultative Group on International Agricultural Research |
| CIMMYT | (Centro Internacional de Mejoramiento de Maíz y Trigo) International Maize and Wheat Improvement Center |
| CRI | Crops Research Institute |
| DA | Days to anthesis |
| DAS | Days after mid-silk |
| DAP | Days after planting |
| DC | Double cross |
| DH | Doubled haploids |
| DS | Days to silking |
| DTC | Double topcross |
| DT | Drought tolerant |
| DUS | Distinctness, uniformity, stability |
| DTMA | Drought-Tolerant Maize for Africa |
| E% | Emergence percentage |
| EASP | Ear aspect |
| EFPD | Effective filling period duration |
| EI | Emergence index |
| EPP | Number of ears per plant |
| ERI | Emergence rate index |
| ESA | East and Southern Africa |
| EV | Experimental variety |
| FAOSTAT | Food and Agriculture Organization Corporate Statistical Database |
| G% | Germination percentage |
| GCA | General combining ability |
| GEI | Genotype by environment interaction |
| GI | Germination index |

| | |
|---|---|
| GR | Growth rate |
| GS | Genomic selection |
| GWS | Genome-wide selection |
| HST | Hybrid seed technology |
| HSGCA | Heterotic groups' specific and general combining ability |
| ICIPE | International Center for Insect Physiology and Ecology |
| IITA | International Institute of Tropical Agriculture |
| IPTT | International Progeny Testing Trial |
| LSD | Least significant difference |
| KARI | Kenya Agricultural Research Institute |
| MAS | Mid-altitude savanna |
| MAS | Marker-assisted selection |
| MABC | Marker-assisted backcrossing |
| MARS | Marker-assisted recurrent selection |
| MB | Marker-assisted breeding |
| MCMC | Markov chain Monte Carlo algorithms |
| MH | Mid-parent heterosis |
| MI | Multiple stress tolerance base index |
| MLN | Maize lethal necrosis |
| MSC | Modified single cross |
| MSV | Maize streak virus |
| MTWC | Modified three-way cross |
| NARIs | National Agricultural Research Institutes |
| NARS | National Agricultural Research Systems |
| NARES | National research and extension system |
| NIP | Noninbred parent |
| NGS | Northern Guinea savanna |
| OPVs | Open-pollinated varieties |
| PASP | Plant aspect |
| PCR | Polymerase chain reaction |
| PHMD | Plant Health Management Division |
| PLHT | Plant height |
| PM | Physiological maturity |
| QEI | QTL by environment interaction |
| QPM | Quality protein maize |
| QTL | Quantitative trait locus |
| RAPD | Random amplified polymorphic DNA |
| RFLP | Restriction fragment length polymorphisms |
| RGR | Relative growth rate |
| RILs | Recombinant inbred lines |
| SCA | Specific combining ability |
| SAFGRAD | Semi-Arid Food Grain Research and Development |
| SNP | Single nucleotide polymorphism |
| SSLP | Simple sequence length polymorphism |
| SSA | Sub-Saharan Africa |

| | |
|---|---|
| SSR | Simple sequence repeat |
| STRs | Short tandem repeats |
| TC | Topcross |
| TWC | Three-way cross |
| USA | United States |
| VC | Varietal cross |
| WA | West Africa |
| WAP | Week after planting |
| WARDA | West Africa Rice Development Association |
| WCA | West and Central Africa |
| WECAMAN | West and Central Africa Collaborative Maize Research Network |

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