MODIFIED RECIPROCAL RECURRENT SELECTION IN SUWAN 1 AND KS 6 MAIZE POPULATIONS

Sujin Jenweerawat

A Thesis Submitted in Partial Fulfillment of the Requirements for the Degree of Doctor of Philosophy in Crop Production Technology

Suranaree University of Technology

Academic Year 2009

การปรับปรุงประชากรข้าวโพดพันธุ์สุวรรณ 1 และ KS 6
โดยวิธีการคัดเลือกซ้ำสลับแบบประยุกต์

นางสาวสุจินต์ เจนวีรวัฒน์

วิทยานิพนธ์นี้เป็นส่วนหนึ่งของการศึกษาตามหลักสูตรปริญญาวิทยาศาสตรดุษฎีบัณฑิต
สาขาวิชาเทคโนโลยีการผลิตพืช
มหาวิทยาลัยเทคโนโลยีสุรนารี
ปีการศึกษา 2552

MODIFIED RECIPROCAL RECURRENT SELECTION IN SUWAN 1 AND KS 6 MAIZE POPULATIONS

Suranaree University of Technology has approved this thesis submitted in partial fulfillment of the requirements for the Degree of Doctor of Philosophy.

Thesis Examining Committee

S. Wonprasaid

(Dr. Sodchol Wonprasaid)

Chairperson

Paisan Laosuwan

(Prof. Dr. Paisan Laosuwan)

Member (Thesis Advisor)

Chokechai Aekata

(Dr. Chokechai Aekatasanawan)

Member

Piyada Tantasawat

(Assoc. Prof. Dr. Piyada Tantasawat)

Member

Sansern Jampatong

(Dr. Sansern Jampatong)

Member

Sukit Limpijumnong

(Prof. Dr. Sukit Limpijumnong)

Vice Rector for Academic Affairs

S. Ningsanond

(Asst. Prof. Dr. Suwayd Ningsanond)

Dean of Institute of Agricultural Technology

สุจินต์ เจนวีรวัฒน์ : การปรับปรุงประชากรข้าวโพดพันธุ์สุวรรณ 1 และ KS 6 โดยวิธีการคัดเลือกซ้ำสลับแบบประยุกต์ (MODIFIED RECIPROCAL RECURRENT SELECTION IN SUWAN 1 AND KS 6 MAIZE POPULATIONS) อาจารย์ที่ปรึกษา : ศาสตราจารย์ ดร.ไพศาล เหล่าสุวรรณ, 219 หน้า.

การปรับปรุงประชากรข้าวโพดสองประชากรที่มีเฮตเทอโรซิสต่อกัน (heterotic pattern) ไปพร้อม ๆ กันเพื่อใช้เป็นแหล่งในการพัฒนาสายพันธุ์ ทำให้นักปรับปรุงพันธุ์พืชสามารถพัฒนาลูกผสมเดี่ยวที่ให้ผลผลิตสูงและมีลักษณะทางการเกษตรอื่น ๆ ที่ดีอย่างต่อเนื่อง การคัดเลือกซ้ำสลับแบบประยุกต์ (modified reciprocal recurrent selection; MRRS) เป็นวิธีการคัดเลือกที่ใช้สายพันธุ์แท้ที่ดีเด่นเป็นตัวทดสอบ สามารถนำมาใช้เพื่อพัฒนาสายพันธุ์ฝั่งใดฝั่งหนึ่งหรือทั้งสองฝั่งของลูกผสมเดี่ยว วัตถุประสงค์ของการศึกษาครั้งนี้ (1) เพื่อปรับปรุงข้าวโพดสองประชากรที่มีเฮตเทอโรซิสต่อกันสำหรับใช้เป็นแหล่งพันธุกรรมเพื่อพัฒนาสายพันธุ์ใหม่ (2) เพื่อพัฒนาสายพันธุ์ที่มีสมรรถนะการรวมตัวทั่วไป (gca) สูง และ/หรือ สมรรถนะการรวมตัวจำเพาะ (sca) สูง และให้ผลผลิตสูง และ (3) เพื่อพัฒนาลูกผสมเดี่ยวที่ให้ผลผลิตสูง การศึกษาครั้งนี้ได้ดำเนินการปรับปรุงพันธุ์โดยวิธี MRRS จำนวน 2 รอบคัดเลือก โดยใช้ประชากรข้าวโพดพันธุ์ Suwan1(S)C11 (ประชากร A) และพันธุ์ KS6(S)C3 (ประชากร B) ซึ่งมีสายพันธุ์แท้ Ki 47 และ Ki 46 เป็นสายพันธุ์ทดสอบตามลำดับ ในแต่ละรอบประกอบด้วย 3 ส่วนหลัก คือ การปรับปรุงประชากร การพัฒนาสายพันธุ์แท้ และการพัฒนาลูกผสม โดยประเมินความก้าวหน้าในการคัดเลือก และทดสอบผลผลิตของสายพันธุ์แท้และลูกผสม ใน 2 สถานที่ ได้แก่ ศูนย์วิจัยข้าวโพดและข้าวฟ่างแห่งชาติ (ไร่สุวรรณ) และศูนย์วิจัยพืชไร่นครสวรรค์ ในปลายฤดูฝน พ.ศ. 2545 และต้นฤดูฝน พ.ศ. 2548 การคัดเลือกใช้ผลผลิตเป็นหลัก โดยพิจารณาลักษณะสำคัญอื่น ๆ ร่วมด้วย เช่น โรคทางใบ การหักล้มของรากและลำต้น

การปรับปรุงประชากรเริ่มจากการผสมตัวเองต้นที่มีลักษณะทางการเกษตรที่ดี ได้สายพันธุ์ชั่วที่ 1 (S_1) ของแต่ละประชากร ผสมสายพันธุ์ S_1 กับสายพันธุ์ทดสอบดังกล่าวตามลำดับ (S_1 testcrosses) และประเมินผลผลิตของลูก S_1 testcrosses จำนวน 250 คู่ผสม ของแต่ละประชากรในปลายฤดูฝน พ.ศ. 2544 ที่ไร่สุวรรณ คัดเลือกลูก testcrosses จำนวน 25 คู่ผสม ที่ให้ผลผลิตสูงในแต่ละประชากร และนำสายพันธุ์ S_2 ของสายพันธุ์ที่ให้ลูก testcross ผลผลิตสูงดังกล่าวมาผสมรวม (recombine) เพื่อสร้างประชากรรอบคัดเลือกที่ 1 นำประชากรรอบคัดเลือกที่ 0 และ 1 มาผสมแบบพบกันหมด (diallel cross) และผสมกับสายพันธุ์ทดสอบ ทำการทดสอบประชากรตัวเอง (populations per se) รอบคัดเลือกที่ 0 และ 1, ลูกผสมระหว่างประชากร (population crosses) และลูกผสมระหว่างประชากรกับสายพันธุ์ทดสอบ (population topcrosses) ผลการทดลองพบว่า ทุกประชากรของรอบคัดเลือกที่ 1 ให้ผลผลิตเพิ่มขึ้นโดยเฉพาะลูกผสมระหว่างประชากร โดย AC1 $\times$ BC1 ให้ผลผลิตสูงกว่า AC0 $\times$ BC0

10.3% (P < 0.05) และยังพบการเพิ่มอิทธิพลของพันธุ์ (variety effects; v_i) และสมรรถนะการรวมตัวทั่วไปของทั้งสองประชากรตัวเอง แต่อิทธิพลของเฮตเทอโรซิสของพันธุ์ (variety heterosis effects; h_i) เพิ่มขึ้นเฉพาะใน BC1 การสร้างประชากรรอบคัดเลือกที่ 2 ใช้วิธีเดียวกันกับการสร้างประชากรรอบคัดเลือกที่ 1 โดยประเมินผลผลิตของลูก C1-S_1 testcrosses ของแต่ละประชากรในต้นฤดูฝน พ.ศ. 2546 ทดสอบประชากรตัวเองรอบคัดเลือกที่ 0, 1 และ 2, ลูกผสมระหว่างประชากรและลูกผสมระหว่างประชากรกับสายพันธุ์ทดสอบ ผลการทดลองพบว่า AC2, AC2 × BC2 และ BC2 × Ki 46 ให้ผลผลิตเพิ่มขึ้น และยังพบการเพิ่มขึ้นของอิทธิพลของพันธุ์ และสมรรถนะการรวมตัวทั่วไปในประชากร AC2 และ BC2 อีกด้วย ค่าเฮตเทอโรซิสเฉลี่ย (average heterosis, $\bar{h}$) มีนัยสำคัญยิ่งทางสถิติ และสมรรถนะการรวมตัวจำเพาะมีแนวโน้มเพิ่มขึ้นใน AC2 × BC2 โดยประชากร B มีส่วนช่วยในเฮตเทอโรซิสของผลผลิตของลูกผสมระหว่างประชากรมากกว่าประชากร A ทั้งรอบคัดเลือกที่ 1 และ 2

สายพันธุ์ จำนวน 25 สายพันธุ์ ที่ใช้ผสมรวมในแต่ละประชากร ได้นำไปใช้ในการพัฒนาลูกผสมระหว่างสายพันธุ์ที่คัดเลือกกับสายพันธุ์ทดสอบ (testcross hybrids; line × tester) และ 10 สายพันธุ์ที่ให้ลูก testcross ผลผลิตสูง 10 อันดับแรก นำไปสร้างลูกผสมระหว่างสายพันธุ์ที่คัดเลือกจากทั้งสองประชากร (interpopulation hybrids; 10 A lines × 10 B lines) ผลการทดสอบผลผลิตของลูกผสมที่ได้จากประชากรรอบคัดเลือกที่ 0 และ 1 พบว่า ลูกผสมที่ให้ผลผลิตสูง 10 อันดับแรกของทุกกลุ่มลูกผสมจากประชากรรอบคัดเลือกที่ 1 (ลูกผสมทั้งหมดที่ได้จากประชากรรอบคัดเลือกที่ 1, AC1 testcross hybrids, BC1 testcross hybrids และ C1 interpopulation hybrids) ให้ผลผลิตเพิ่มขึ้นอย่างมีนัยสำคัญ เปรียบเทียบกับลูกผสมที่ให้ผลผลิตสูง 10 อันดับแรกของแต่ละกลุ่มลูกผสมที่ได้จากประชากรรอบคัดเลือกที่ 0 ลูกผสมจากประชากรรอบคัดเลือกที่ 1 ที่ให้ผลผลิตสูง 10 อันดับแรกยังให้ผลผลิตสูงไม่แตกต่างจากลูกผสมเปรียบเทียบพันธุ์สุวรรณ 4452 แต่มีค่าเฉลี่ยความสูงต้นสูงกว่าพันธุ์เปรียบเทียบ (P < 0.05) และลูกผสม testcross hybrids มีศักยภาพในการให้ผลผลิตสูงกว่า interpopulation hybrids การคัดเลือกโดยใช้ผลผลิตแสดงให้เห็นว่า ผลของยีนแบบข่ม (dominance) ของลักษณะผลผลิตเพิ่มขึ้นในขณะที่ผลของยีนแบบบวก (additive) ลดลง ซึ่งเป็นผลให้ได้ลูกผสม interpopulation hybrids ที่มีผลผลิตสูง สำหรับลักษณะอื่น ๆ พบว่า ผลของยีนแบบบวกมีบทบาทสำคัญในลักษณะวันสลัดละอองเกสร 50% วันออกไหม 50% ความสูงต้นและฝัก การหักล้มของต้นและราก โรคทางใบ ความชื้นเมล็ด และเปอร์เซ็นต์กะเทาะเมล็ด

การคัดเลือกแบบบันทึกประวัติ (pedigree selection) ได้นำมาใช้ในการพัฒนาสายพันธุ์ในแต่ละประชากร โดยคัดเลือกสายพันธุ์ที่ให้ลูก testcross ที่มีผลผลิตสูง ผลการทดสอบผลผลิตของสายพันธุ์พบว่า 25 สายพันธุ์ ของประชากร AC1 และ BC1 ให้ค่าเฉลี่ยผลผลิตสูงกว่า 25 สายพันธุ์ ของประชากร AC0 และ BC0 23% และ 28% ตามลำดับ โดยเปรียบเทียบกับสายพันธุ์เปรียบเทียบ Ki 47 และมี

วันสลัดละอองเกสร 50% และวันออกไหม 50% เพิ่มขึ้นอย่างมีนัยสำคัญ นอกจากนี้สายพันธุ์ที่คัดเลือกยังสามารถนำไปใช้ในการผลิตลูกผสม testcross hybrids และ interpopulation hybrids

การคัดเลือกโดยวิธี MRRS มีประสิทธิภาพในการปรับปรุงผลผลิตทั้งในส่วนของประชากรและสายพันธุ์ตัวเอง และลูกผสม population cross, population topcross, testcross hybrid และ interpopulation hybrid ซึ่งผลการทดลองแสดงให้เห็นว่า การคัดเลือกดังกล่าวมีประสิทธิภาพในการปรับปรุงอิทธิพลของยีนแบบบวกและไม่เป็นแบบบวก การคัดเลือกวิธีนี้สามารถพัฒนาสายพันธุ์และลูกผสมที่มีศักยภาพในการให้ผลผลิตสูงไปพร้อม ๆ กัน

สาขาวิชาเทคโนโลยีการผลิตพืช | ลายมือชื่อนักศึกษา____________
ปีการศึกษา 2552 | ลายมือชื่ออาจารย์ที่ปรึกษา____________
ลายมือชื่ออาจารย์ที่ปรึกษาร่วม____________

SUJIN JENWEERAWAT : MODIFIED RECIPROCAL RECURRENT SELECTION IN SUWAN 1 AND KS 6 MAIZE POPULATIONS. THESIS ADVISOR : PROF. PAISAN LAOSUWAN, Ph.D., 219 PP.

MRRS/INBRED TESTER/POPULATION/LINE/HYBRID/GCA/SCA

The simultaneous improvement of two heterotic maize populations as the sources for developing inbred lines can help breeders to continuously develop single-cross hybrids which have high yields and good agronomic traits. Modified reciprocal recurrent selection (MRRS) is a selection method using elite inbred lines as testers to develop lines for one or both sides of single-cross hybrids. The objectives of this study were (i) to improve two heterotic maize populations as germplasm sources for new inbred lines, (ii) to develop inbred lines with high general combining ability (gca) and/or high specific combining ability (sca) and high yield, and (iii) to develop high-yielding single-cross hybrids. In this study, two cycles of MRRS were conducted in Suwan1(S)C11 (population A) and KS6(S)C3 (population B) maize populations with respective inbred testers, Ki 47 and Ki 46. Each cycle consisted of three major parts: population improvement, inbred line development and hybrid development. Progress from selection, inbred lines and hybrids were evaluated at two locations: National Corn and Sorghum Research Center (Suwan Farm) and Nakhon Sawan Field Crops Research Center, in late rainy season, 2002 and early rainy season, 2005. The selection was based mainly on grain yields and other important traits, such as foliar diseases, root and stalk lodging, etc. which were also assessed.

The population improvement started with selfing plants which had good agronomic traits to develop S_1 lines of each population. The S_1 lines were crossed with

the respective inbred testers and 250 S_1 testcrosses of each population were evaluated for yield in late rainy season, 2001 at Suwan Farm. The 25 top yielding testcrosses were selected from each and their corresponding S_2 lines were recombined to form C1 populations. The C0 and C1 populations were crossed among them in a diallel scheme and crossed with the respective inbred testers. The C0 and C1 populations per se, their population crosses and their topcrosses were evaluated. The results showed the improvement for grain yield for all C1 populations especially population cross. The cross of AC1 × BC1 yielded higher than the AC0 × BC0 for 10.3% ($P < 0.05$). Variety effects (v_i) and gca effects were also improved for both populations per se, while variety heterosis effect (h_i) was improved only for BC1. The C2 populations were formed in the same manner as their C1 populations. The C1-S_1 testcrosses of each population were evaluated for yields in early rainy season, 2003. The C0, C1 and C2 populations per se, their population crosses and their topcrosses were evaluated. The results showed that the AC2, AC2 × BC2 and BC2 × Ki 46 were improved for grain yields. The AC2 and BC2 were also improved for variety effects and gca effects. Average heterosis ($\bar{h}$) was highly significant, and sca effects seemed to be improved for the AC2 × BC2. The population B contributed more than the population A in the population crosses for heterosis of grain yields in both C1 and C2.

The 25 lines used for recombining in each population were further used to develop testcross hybrids (line × tester), and 10 lines which corresponded to the top 10 testcrosses were used to develop interpopulation hybrids (10 A lines × 10 B lines). Yield trials of C0 and C1 hybrids showed significant improvement for grain yields in all top 10 C1 hybrid groups (C1 hybrids, AC1 testcross hybrids, BC1 testcross hybrids and C1 interpopulation hybrids) compared with the top 10 C0 hybrid groups. The top

10 C1 hybrids also had as high yields as the hybrid check, Suwan 4452, but higher mean for plant height ($P < 0.05$). The testcross hybrids had higher potential for yields than the interpopulation hybrids. The selection for grain yields showed that dominance variance of this trait increased while additive variance decreased, which resulted in the development of high-yielding interpopulation hybrids. For other traits, additive variance had a major role for days to 50% anthesis and silking, plant and ear heights, stalk and root lodging, foliar diseases, grain moisture, and grain shelling percentage.

Pedigree selection was used for line development in each population. The lines developed were selected on the basis of their testcross performance. The results from yield trials of the selected lines showed that the 25 lines of AC1 and BC1 had a higher mean for grain yields than the 25 lines of AC0 and BC0 for 23% and 28%, respectively, relative to the inbred check, Ki 47. However, the number of days to 50% anthesis and silking increased significantly. In addition, the selected lines can be used in both testcross and interpopulation hybrids.

The MRRS program was effective in improving grain yield of both populations and lines per se and hybrid combinations (population crosses, population topcrosses, testcross hybrids and interpopulation hybrids). These suggested that the selection was effective in improving both additive and nonadditive gene effects. Potential high-yielding hybrids and their parental lines can be developed simultaneously from the program.

School of Crop Production Technology Student's Signature Sujin Jenweerawat

Academic Year 2009 Advisor's Signature Paisan Laosuwan.

Co-advisor's Signature Chokechai Aekat

ACKNOWLEDGEMENTS

This research had been completed successfully due to all support by many people from many institutes. The individuals deserve recognition and credit as follows:

Suranaree University of Technology, Nakhon Ratchasima: I would like to personally thank Prof. Dr. Paisan Laosuwan, thesis advisor, for giving me a chance to study with a scholarship supported by the Royal Golden Jubilee Ph.D. Program, imparting knowledge especially plant breeding, statistical analysis and research writing, supervising, and paying attention to all his students. Assoc. Prof. Dr. Piyada Tantasawat for providing a job for financial support and her kind guidance. Dr. Sodchol Wonprasaid, chairperson, for his kind guidance.

The Thailand Research Fund (TRF) for financial support through the Royal Golden Jubilee Ph.D. Program (the RGJ grant, no. PHD/0070/2544; and the BGJ award, no. BGJ4680022).

National Corn and Sorghum Research Center, Nakhon Ratchasima: A special thanks goes to Dr. Chokechai Aekatasanawan (thesis co-advisor), Senior Expert Researcher, for developing my project idea, suggesting corn breeding techniques and theory, and all his advice. Dr. Sansern Jampatong for providing some genetic materials, i.e., seeds of base populations (Suwan1(S)C11 and KS6(S)C3), hybrid seeds from private sector and checks, and his advice. Mr. Chatpong Balla and Mr. Sakol Chaisri for all their kind support. The research center and all staff for mainly serving this research.

Department of Agronomy, Iowa State University, Ames, Iowa, USA: I would like to thank Prof. Dr. Arnel R. Hallauer, thesis co-advisor, for his continuous support in this project and all his kind guidance. Prof. Dr. Kendall R. Lamkey for providing statistical program in the computer laboratory and his kind advice. Paul White for his hospitality and suggesting field work. Mary Lents for facilitating contact with Prof. Dr. Arnel R. Hallauer and providing secretarial assistance. Thai Student Association at Iowa State University especially Dr. Suphalat Chittamvanich, Dr. Kageeporn Wongpreedee, Dr. Thanathip Suwanasopee and Dr. Buppa Kongsamai for their kind guidance.

Nakhon Sawan Field Crops Research Center, Nakhon Sawan: I would like to thank the research center, including Mr. Pichet Grudloyma, Mr. Somrak Noradechanon, Mr. Surapong Prasitwattanaseree and all staff in the plant breeding group, for providing testing location, workers and all their kind support.

Prof. Dr. Manjit S. Kang and Dr.Yudong Mike Zhang for providing the DIALLEL-SAS05 program and their kind support for the program analysis.

Asst. Prof. Dr. Choosak Jompuk for his kind advice on diallel analysis.

Asst. Prof. Dr. Panwadee Sopannarath for her kind advice on statistical program for Design II analysis.

Especially, I would like to express a grateful thanks to my beloved father and mother (Mr. Boonyen and Mrs. Nuansri) for financial and moral support and taking good care of me. Mrs. Rojjana Nasseys, my older sister, for financial support. Ms. Wanwimol (my aunt), my younger sister and brother, and friends for their love and care.

Sujin Jenweerawat

TABLE OF CONTENTS

Page

ABSTRACT (THAI) I

ABSTRACT (ENGLISH) IV

ACKNOWLEDGEMENTS VII

TABLE OF CONTENTS IX

LIST OF TABLES XIII

LIST OF FIGURES XXIII

LIST OF ABBREVIATIONS XXIV

CHAPTER

I INTRODUCTION 1

II REVIEW OF THE LITERATURE 3

2.1 Maize production and research in Thailand 3

2.2 The concept of recurrent selection 6

2.3 The modified reciprocal recurrent selection (MRRS) 8

A. Development of MRRS 8

B. Use of inbred as tester 11

C. Relative efficiency of MRRS 13

D. Gene action related to MRRS 17

2.4 Variety cross diallel: Gardner-Eberhart Analysis 20

2.5 North Carolina Design II 26

III MATERIALS AND METHODS 29

TABLE OF CONTENTS (Continued)

Page

3.1 Genetic materials 29

3.1.1 Germplasms used in the selection 29

3.1.2 Check varieties 30

3.2 Methods 32

3.2.1 Population improvement 32

3.2.2 Hybrid development 40

3.2.3 Inbred line development 45

3.3 Locations of experiment 52

3.3.1 National Corn and Sorghum Research Center (NCSRC; Suwan Farm) 52

3.3.2 Nakhon Sawan Field Crops Research Center (NSWFCRC) 52

3.4 Collection of data 53

3.5 Statistical procedure and analysis 58

3.5.1 Yield trials 58

3.5.2 Gardner-Eberhart Analysis II and Analysis III 59

3.5.3 Design II model analysis 63

3.5.4 Tests of significance for two means 65

IV RESULTS AND DISCUSSION 66

4.1 Population improvement 66

4.1.1 C0-S_1 testcross evaluation 66

TABLE OF CONTENTS (Continued)

Page

4.1.2 Yield evaluation for C0 and C1 populations per se, their population crosses and their population topcrosses ... 67

4.1.3 Evaluation of C0 and C1 populations per se and their population crosses according to Gardner-Eberhart Analysis II and Analysis III ... 73

4.1.4 C1-S_1 testcross evaluation ... 78

4.1.5 Yield evaluation for C0, C1 and C2 populations per se, their population crosses and their population topcrosses ... 81

4.1.6 Evaluation of C0, C1 and C2 populations per se and their population crosses according to Gardner-Eberhart Analysis II and Analysis III ... 86

4.2 Hybrid development ... 93

4.2.1 Yield evaluation for all C0 hybrids ... 93

4.2.2 Analyses for genetic variances and gca and sca effects from 100 C0 interpopulation hybrids according to Design II ... 98

4.2.3 Yield evaluation for all C1 hybrids and the selected C0 hybrids ... 103

4.2.4 Analyses for genetic variances and gca and sca effects from 100 C1 interpopulation hybrids according to Design II ... 117

TABLE OF CONTENTS (Continued)

Page

4.3 Inbred line development 126

4.3.1 Yield evaluation for the selected C0 lines 126

4.3.2 Yield evaluation for the selected C1 and C0 lines.......... 129

V CONCLUSIONS 143

REFERENCES 147

APPENDICES 159

APPENDIX A GERMPLASMS ASSEMBLED IN THAI COMPOSITE #1 AND KS 6 MAIZE POPULATIONS 160

APPENDIX B ADDITIONAL DATA FOR POPULATION IMPROVEMENT.. 163

APPENDIX C ADDITIONAL DATA FOR HYBRID DEVELOPMENT 182

APPENDIX D ADDITIONAL DATA FOR INBRED LINE DEVELOPMENT 204

APPENDIX E COLLECTION OF DATA FOR HYBRID AND INBRED LINE DESCRIPTION 216

BIOGRAPHY 219

LIST OF TABLES

Table **Page**

3.1 Sum of squares of n parents and their n(n – 1)/2 variety crosses for variety and heterosis effects for Gardner-Eberhart Analysis II (Gardner and Eberhart, 1966) 61

3.2 Sum of squares of n parents and their n(n – 1)/2 variety crosses for general and specific combining ability for Gardner-Eberhart Analysis III (Gardner and Eberhart, 1966) 62

4.1 Mean squares from analyses of variance of 10 traits of the testcrosses of AC0-S_1 at Suwan Farm in the 2001 late rainy season 68

4.2 Mean squares from analyses of variance of 10 traits of the testcrosses of BC0-S_1 at Suwan Farm in the 2001 late rainy season 68

4.3 Grain yield of C0-S_1 testcrosses compared with Suwan 3851 (hybrid check) at Suwan Farm in the 2001 late rainy season.. 69

4.4 Mean squares from analyses of variance of 10 traits of 14 populations and two population checks from data combined over two locations in the 2002 late rainy season... 71

4.5 Mean grain yield of C0 and C1 populations compared with Suwan5(S)C3 (population check) from data combined over two locations in the 2002 late rainy season... 72

4.6 Mean squares from Gardner-Eberhart Analysis II and Analysis III of 10 traits from four populations per se and their six diallel crosses, from

LIST OF TABLES (Continued)

Table **Page**

data combined over two locations in the 2002 late rainy season 74

4.7 Estimates of variety effects (v_i) from Gardner-Eberhart Analysis II of 10 traits from four populations per se and their six diallel crosses, from data combined over two locations in the 2002 late rainy season 75

4.8 Estimates of variety heterosis effects (h_i) and average heterosis ($\bar{h}$) from Gardner-Eberhart Analysis II of 10 traits from four populations per se and their six diallel crosses, from data combined over two locations in the 2002 late rainy season 76

4.9 Estimates of gca and sca effects from Gardner-Eberhart Analysis III of 10 traits of four populations per se and their six diallel crosses, from data combined over two locations in the 2002 late rainy season 77

4.10 Mean squares from analyses of variance of 10 traits of the testcrosses of AC1-S_1 at Suwan Farm in the 2003 early rainy season 80

4.11 Mean squares from analyses of variance of 10 traits of the testcrosses of BC1-S_1 at Suwan Farm in the 2003 early rainy season 80

4.12 Grain yield of C1-S_1 testcrosses compared with Suwan 3851 (hybrid check) at Suwan Farm in the 2003 early rainy season....................... 81

4.13 Mean squares from analyses of variance of 10 traits of 27 populations and three population checks from data combined over two locations in the 2005 early rainy season 83

4.14 Mean grain yield of C0, C1 and C2 populations compared with

LIST OF TABLES (Continued)

Table **Page**

Suwan5(S)C4 (population check) from data combined over two locations in the 2005 early rainy season 85

4.15 Mean squares from Gardner-Eberhart Analysis II and Analysis III of 10 traits from six populations per se and their 15 diallel crosses, from data combined over two locations in the 2005 early rainy season 87

4.16 Estimates of variety effects (v_i) from Gardner-Eberhart Analysis II of 10 traits from six populations per se and their 15 diallel crosses, from data combined over two locations in the 2005 early rainy season 88

4.17 Estimates of variety heterosis effects (h_i) and average heterosis ($\bar{h}$) from Gardner-Eberhart Analysis II of 10 traits from six populations per se and their 15 diallel crosses, from data combined over two locations in the 2005 early rainy season 89

4.18 Estimates of gca and sca effects from Gardner-Eberhart Analysis III of 10 traits of six populations per se and their 15 diallel crosses, from data combined over two locations in the 2005 early rainy season 91

4.19 Mean squares from analyses of variance of 10 traits of C0 hybrids from data combined over two locations in the 2002 late rainy season 95

4.20 Grain yield of C0 hybrids compared with Suwan 3851 (hybrid check) from data combined over two locations in the 2002 late rainy season 96

4.21 Means of 10 traits of the top 10 C0 hybrids of each group compared with Suwan 3851 (hybrid check) from data combined over two locations in

LIST OF FIGURES

Figure **Page**

3.1 Breeding scheme for the modified reciprocal recurrent selection program........50

3.2 Breeding scheme for the part of population improvement...............................51

1B Sample ears of C0, C1 and C2 populations per se, their population crosses and their population topcrosses to inbred testers compared with three population checks (Suwan1(S)C12, Suwan3(S)C4 and Suwan5(S)C4) 181

1C Sample ears of the top-yielding C0 hybrid and the top 10 yielding C1 hybrids compared with six hybrid checks (Suwan 4452, KSX 4601, NK 40, PAC 999, BIG 919 and DK 888)....................................203

1D Sample ears of the three C0 and 10 C1 lines which were components of the high-yielding hybrids and had high yield compared with six inbred checks (Kei 0102 or Ki 48, Kei 0303, Kei 0301, Ki 45, Ki 46 and Ki 47).......215

LIST OF ABBREVIATIONS

RRS	=	Reciprocal Recurrent Selection
MRRS	=	Modified Reciprocal Recurrent Selection
NCSRC	=	National Corn and Sorghum Research Center (Suwan Farm)
NSWFCRC	=	Nakhon Sawan Field Crops Research Center
A	=	Suwan1(S)C11
B	=	KS6(S)C3
D	=	Dry season (November-February)
E	=	Early rainy season (March-June)
L	=	Late rainy season (July-October)
C	=	Cycle of selection
S	=	Self-pollination

CHAPTER I

INTRODUCTION

Maize (*Zea mays* L.) is an important economic field crop of Thailand. It is cultivated mainly for animal feed. The most recent statistics showed a decrease in the harvested area of the crop in the last ten years (1997-2006). The present area is 0.89 million hectares with the production of 3.69 million tons and the average yield of 4,113 kg ha^{-1} (Office of Agricultural Economics, Online, 2006b). This production is not sufficient for domestic consumptions. The major planted areas of maize are in the North, Northeast and Central Plain of the country (Office of Agricultural Economics, Online, 2006c). At present, 99.77% of maize areas in Thailand are planted to hybrid varieties, especially single-cross hybrids (Office of Agricultural Economics, Data File, 2005). The single-cross hybrid is productive and uniform in the appearance, maturity and yield potential. Therefore, breeding of maize varieties is focused on single-cross hybrids.

As of the late 1970s, when research on maize hybrid was initiated, most inbred lines were developed from the intrapopulation improvement, especially S_1 recurrent selection. Then, the inbred lines were tested for general and specific combining ability (gca and sca) to identify productive single-cross combinations. The simultaneous improvement of two heterotic maize populations to extract inbred lines from each population helps the development of single-cross hybrids to be faster. Modified reciprocal recurrent selection (MRRS) is a method which improves two heterotic populations simultaneously and uses inbred lines as testers. Lines derived from the improved populations of MRRS also could be used immediately to produce hybrids with the inbred testers (Menz Rademacher et al., 1999). Modern inbred lines should be more vigorous and productive than those developed earlier and kernel size and shape approach that of hybrids. The improvements of modern inbred lines make it possible for seed producers to market and the farmers to grow single-cross hybrids (Poehlman and Sleper, 1995).

Aekatasanawan (1999) stated that conventional maize breeding, which has been used in Thailand since the maize research was initiated, plays an important role in the increase of production. It started with the selection of promising exotic germplasm, followed by a systemic population formation and recombination. The base and advanced populations have been also improved continuously, especially by S_1 recurrent selection method. The method is highly efficient to accumulate favorable gene frequencies in additive manner. These resulted in releasing many outstanding open-pollinated varieties such as Suwan 1, Suwan 2, Suwan 3 and Suwan 5. These varieties can be also used as potential sources for extracting elite inbred lines, particularly in latter cycles. The exploitation of maximized heterosis in single-cross hybrids from these inbred lines gave higher yield than those of open-pollinated varieties by 30-50%.

The objectives of this study were (i) to improve two heterotic maize populations by using modified reciprocal recurrent selection for use as source populations for new inbred lines; (ii) to extract inbred lines with high general combining ability (gca) and/or high specific combining ability (sca) and high yield; and (iii) to develop high-yielding single-cross hybrids.

CHAPTER II

REVIEW OF THE LITERATURE

2.1 Maize production and research in Thailand

Maize is one of the most important economic field crops of the world. It is cultivated mainly for animal feed, human consumption and industrial uses for the production of flour, oil, sugar, syrup, vinegar, soap, alcohol, plastic, film, etc. The world production of maize in 2006 was about 695 million tons from the harvested area of 143 million hectares with the average yield of 4,869 kg ha^{-1}. Countries with high maize production in 2006 were the United States of America, China, Brazil, Mexico and India, respectively (Office of Agricultural Economics, Online, 2006a).

Commercial maize production in Thailand began in 1932 when Prince Sithiporn, the Director General of the Department of Agriculture, introduced two varieties of dent corn, Nicholson's Yellow Dent and Mexican June, into Thailand. The varieties were multiplied and subsequently distributed to Northeastern Thailand, the first commercial production area (Sriwatanapongse et al., 1993). Thailand maize research was initiated by the Department of Agriculture, Ministry of Agriculture and Co-operatives in 1950 and Kasetsart University in 1958 (Jampatong et al., 2001).

In the 1950s and 1960s, the average yield of maize increased due to the composite of Caribbean collections, known as "Guatemala" (C-110 or Tequisate Golden Yellow Flint) (Aekatasanawan, 1997). The variety was developed in Guatemala by the late I.E. Melhus, Professor Emeritus at Iowa State University. It was successful in Indonesia as

"Metro" and showed broad adaptation in Thailand. It was tolerant to some diseases and insect pests, had good grain texture (flint) and acceptable color (orange yellow) despite being tall, moderate yield and susceptible to downy mildew disease (Sriwatanapongse et al., 1993). The Department of Agriculture released "Guatemala" and supplied seeds to farmers in 1954. Later, Ampol Senanarong, the team leader of the Department of Agriculture Maize Breeding Program, improved Guatemala by controlled mass selection method and released "Phraputtabat" varieties such as PB 3 and PB 5 during 1961-1975 (Aekatasanawan et al., 1998).

In the 1970s, the average yield of maize stayed at the same level due to the susceptibility of these maize varieties to corn downy mildew disease (*Peronosclerospora sorghi* (Weston & Uppal) C.G. Shaw) (Aekatasanawan et al., 1998). The corn downy mildew was found sporadically along banks of the river at Nakhon Sawan in 1966 and frequently in larger area in 1968. During the early 1970s, the disease became a major threat to Thai maize production (Jampatong et al., 2001). Subsequently, the varieties were replaced by two resistant varieties: Thai DMR 6 in 1972 and Suwan 1 in 1975. The two open-pollinated varieties (OPVs) were developed by the Department of Agriculture and Sujin Jinahyon (the team leader of the Kasetsart University Maize Breeding Program), respectively (Aekatasanawan et al., 1998). Suwan 1 was approved by the Ministry of Agriculture and released as a standard variety in 1975. It became an outstanding and widely-adapted variety in the tropical lowland countries. After releasing Suwan 1, an early OPV with downy mildew resistance named Suwan 2 was released in 1979 (Aekatasanawan et al., 1998; Jampatong et al., 2001). In the late 1970s, hybrid maize research was started by Kasetsart University and multinational seed companies while the effort on population development still continued. Sujin Jinahyon, the former maize breeding project leader, initiated the Kasetsart University hybrid maize breeding program with his vision of hybrid maize in Thailand in 1978. It was the same period when many major foreign and local seed companies began to invest in Thailand during the late 1970s to early 1980s by establishing research station and processing plants (Jampatong et al., 2001).

In the 1980s, hybrid maize including double crosses, three-way crosses and some nonconventional hybrids had high proportions in hybrid seeds used (Aekatasanawan et al., 1998). Thai farmers began to grow hybrid maize in 1981. Then the first commercial single-cross hybrid in Thailand, Suwan 2301, was released in the subsequent year by the National Corn and Sorghum Research Center, Kasetsart University. As a consequence, the planted area for improved OPV was gradually replaced by hybrid varieties (Jampatong et al., 2001). The beginning of Kasetsart maize hybrid breeding program used Suwan 1 as a base germplasm for the development of new populations because the program was still focusing on releasing improved OPVs to farmers. Then the two OPVs developed from the program in 1983 and 1984 were Suwan 3 and Suwan 5 which contained 80% and 32% of Suwan 1 germplasm, respectively. A non-Suwan 1 population was first developed in 1983 named KS 6. It had been used in the hybrid program from the two released inbred lines, Ki 44 and Ki 47. Subsequently, KS 23, a broad base synthetic containing some temperate and subtropical germplasm was formed in 1987 to use in hybrid breeding program as a partner of Suwan 1 and Suwan 1 derivatives (Jampatong et al., 2001). In this decade, the two OPVs were released. Suwan 3, a medium maturing variety with rust and downy mildew resistance, was released by Kasetsart University in 1987 (Chutkaew et al., 1989, quoted in Aekatasanawan et al., 1998; Jampatong et al., 2001). Nakhon Sawan 1 was released by the Department of

Agriculture in 1989 (Aekatasanawan et al., 1998).

In the 1990s, an average yield during 1990-1996 was 2,928 kg ha^{-1} higher than those of the 1970s (50.1%) and 1980s (24.6%) (Aekatasanawan et al., 1998). Suwan 5, a medium maturing variety with downy mildew resistance, was only one OPV released in 1993 by Kasetsart University (Aekatasanawan et al., 1993, quoted in Aekatasanawan et al., 1998; Jampatong et al., 2001). Since the mid-1990s, single-cross hybrid has played an important role due to the potential for higher yield and the promotion from the Department of Agricultural Extension, Kasetsart University and private seed companies (Aekatasanawan, 1997). While double-cross hybrid diminished gradually, three-way cross hybrid has increased proportionally due to a higher potential for yield and more uniformity. The increasing yield in this decade resulted from both genetic improvement as mentioned above and applications of better cultural practices and increases of inputs (fertilizer, weed control, etc.) (Aekatasanawan et al., 1998).

2.2 The concept of recurrent selection

Recurrent selection is a breeding system used for population improvement. The method consists of repeated hybridization, cycles of selection and recombination to increase the frequency of favorable alleles of characters, especially seed yield (Allard, 1960). The method was found to increase mean performance of improved populations while maintaining genetic variation for continuous improvement of the populations. The improved populations can be used as improved varieties, sources for extracting inbred lines to be used in producing hybrid varieties and sources of foundation stocks for synthetic varieties. Four types of recurrent selection are distinguished according to the means to identify plants with desirable attributes: simple recurrent selection, recurrent selection for general combining ability, recurrent selection for specific combining ability and reciprocal recurrent selection (Allard, 1960). The methods of recurrent selection known as methods used for population improvement also can be classified into two groups, intrapopulation improvement and interpopulation improvement. Briefly, most methods of recurrent selection consist of three phases: (i) establishing progenies for evaluation, (ii) evaluation of progenies and (iii) recombination of selected genotypes to form the population for the next cycle of selection (Hallauer, 1985). Stoskopf et al. (1993) concluded that recurrent selection is designed to increase mean performance of the improved populations and maintain genetic variability to permit continued improvement and opportunity for selection of superior genotypes in any cycle.

The obvious success of recurrent selection in the improvement of maize population in Thailand demonstrates in Suwan 1 population which has been improved by S_1 recurrent selection since 1970 (Sriwatanapongse et al., 1993). Suwan 1 is not only an outstanding variety but also an important source of elite inbred lines used in commercial production of hybrids (Inseechandrastitya Institute for Crops Research and Development, 1993). Aekatasanawan et al. (1996) concluded that S_1 recurrent selection was highly efficient to increase mean grain yield of both populations per se and their combining ability of 11 cycles of Suwan 1 with inbred testers. In addition, it can improve other agronomic traits of the populations per se in the desired direction, i.e. lower root and stalk lodging, better foliar disease resistance, longer husk cover and more ears plant^{-1}.

2.3 The modified reciprocal recurrent selection (MRRS)

A. Development of MRRS

Reciprocal recurrent selection (RRS) was originally proposed by Comstock, Robinson and Harvey (1949) for improvement of commercial hybrids in diploid organisms. The method was designed to improve performance of the cross between two heterotic populations which included selection for both general and specific combining ability. RRS consists of two source populations designated as A and B which should be as genetically divergent as possible and uses the opposite populations as reciprocal testers. First season, S_0 or S_1 plants from the population A are self-pollinated and also crossed to plants from the population B and vice versa. Second season, the testcross progenies from both sources are evaluated separately in replicated yield trial. Third season, the selected plants from testcross progenies are intermated using their selfed seed produced from the first season to form improved populations for the next cycle of selection. Eberhart et al. (1973) stated that maximizing the rate of population cross improvement should be the main objective for RRS because the improvement of derived single-cross hybrids is expected to parallel the improvement of the population cross. Likewise, an increase in the level of heterosis of population cross is expected to associate with a further increase in the heterosis expressed in crosses between lines selected from each population (Martin and Hallauer, 1980; Eyherabide and Hallauer, 1991a; 1991b; Keeratinijakal and Lamkey, 1993a).

However, RRS has not been widely adopted by maize breeders because RRS is not as efficient for recovery of inbred lines as other methods of inbred development (Russell and Eberhart, 1975). Therefore, Russell and Eberhart (1975) proposed a modified RRS (MRRS) as an alternative to RRS to overcome this limitation. They suggested the use of inbred lines derived from the opposite populations as testers instead of the population themselves. They also suggested the use of an elite inbred line as tester and expected that gain from selection from MRRS would be greater than RRS due to the greater genetic variance among the testcrosses. The variety cross including derived hybrids would also show maximum improvement resulted from simultaneous improving the two complementary populations (Eberhart et al., 1973; Russell and Eberhart, 1975). MRRS is a useful recurrent selection scheme for supplementing pedigree selection programs because the scheme supports line development for hybrids which is the main objective in most pedigree selection programs (Hallauer and Miranda, 1988; Agrawal, 1998).

Two populations used for improvement by MRRS should have adequate genetic variability, have high mean performance and express heterosis in crosses (Hallauer and Miranda, 1988; Agrawal, 1998). Lambert (1984) selected two synthetics, BS10 and RSSSC, for initiating a MRRS program in a high yield environment (HYE). They were selected because they gave high grain yields and high average grain yields in F_1 population crosses. They also showed better average stalk lodging or productive plants either populations per se or population crosses. Camussi et al. (1988) constituted two base populations, Synthetic A and Synthetic B, to start a MRRS program for selecting superior genotypes to be used in temperate-warm areas as a second crop. Synthetic A was formed by intermating the three Group A populations and inbred line W117. Synthetic B was formed by intermating the three Group B populations and inbred line A632. The three Group A populations and W117 demonstrated heterosis with the three Group B populations and A632. Also, the six populations showed the best mean performance. Aekatasanawan et al. (1990) reported that the most useful heterotic pattern from the variety diallel cross among 10 open-pollinated varieties was Suwan1(S)C11 × KS6(S)C2 (Suwan 1-KS 6 pattern). The cross was the second highest yielder which was higher than KTX 2602, a hybrid check. It gave mid-parent heterosis of 18.5% for grain yield. Also, its parents had high variety and general combining ability effects. They stated that these two populations should be potential populations for reciprocal recurrent selection program.

Inbred lines used as testers for MRRS should show heterosis when they were combined into a single cross (Russell and Eberhart, 1975; Hallauer and Miranda, 1988; Agrawal, 1998; Menz Rademacher et al., 1999). The advantage of using an inbred line tester is the reduction of sampling error in heterogeneous testers (Russell et al., 1992; Landi and Frascaroli, 1995; Menz Rademacher et al., 1999). Superior lines developed from the improved populations of MRRS could be used immediately to produce hybrids with the inbred testers if the testers are elite lines being used in commercial hybrid production (Horner et al., 1972; Russell et al., 1992; Menz Rademacher et al., 1999). In addition, the additive effects of lines selected by an inbred tester allow the use of the selected lines in combination with other elite inbred lines for hybrid development (Narro et al., 2003).

A proper choice of the inbred testers is an important factor responsible for the success of MRRS (Russell et al., 1992; Landi and Frascaroli, 1995; Menz Rademacher et al., 1999). The choice of inbred tester was suggested by Hull (1945) who emphasized that homozygous tester should be used for selection for specific combining ability. Correspondingly, Stoskopf et al. (1993) stated that the choice of inbred tester was important for the success of recurrent selection for specific combining ability. Hull (1945), Horner et al. (1963) and Horner et al. (1989) suggested that the tester line should primarily be proved to have high general combining ability and good agronomic traits. Horner et al. (1963) chose inbred F6, one of the parents of a double cross, as a tester mainly because of its vigor, uniformity and ease of handling in the nursery. This line had an average combining ability and seemed to carry dominant genes for low kernel-row number. Walejko and Russell (1977) stated that an obvious tester should be an inbred line which is widely used in the seed industry as similarly suggested by Stoskopf et al. (1993). Moreover, inbred testers can be replaced by better lines as the program progresses with no adverse effects on the population improvement achieved by previous testers (Horner et al., 1973; Walejko and Russell, 1977; Horner et al., 1989; Stojšin and Kannenberg, 1994a).

B. Use of inbred as tester

In the use of testcross, selection of tester is the most important step that provides the best discrimination among genotypes according to the purposes of selection (Hallauer and Miranda, 1988). Hull (1945) hypothesized that the most efficient tester could be an inbred line which has a low frequency of favorable alleles. Rawlings and Thompson (1962) showed that a low gene frequency in the tester gave a greater genetic variance among testcross progenies than the tester with a high gene frequency in the range of partial to complete dominance of genes. Their results were in favor of the theory that low performing testers, presumably with low frequency of favorable alleles at important loci, were the most effective. Horner et al. (1963) reported that the use of inbred tester revealed larger genetic variance among the testcrosses than a broad base tester. Horner et al. (1973) concluded that inbred testers having many important loci with gene frequency of zero (homozygous recessive) would result in larger testcross variance and more successful selection of dominant favorable alleles than a broad base tester, which probably has intermediate gene frequencies at most loci. Lamkey and Hallauer (1986) reported that the genetic variance among testcross family means was greater when a low-yielding tester was used than when a high-yielding tester was used only for the low-yielding parents. The results suggested that the increase in genetic variance obtained by using a low-yielding tester was mainly because of lines with low performance per se. Smith (1986) reported results from the computer simulation that the use of a high performance tester will reduce the genetic variance among testcrosses. In addition, tester with high favorable alleles reduced the correlation between line per se and testcross performance. This was because increased favorable alleles reduced the covariance between line per se and testcross, thus, decreased correlations. This was known as the masking effect by testers (Smith, 1986; Jampatong et al., 1988; Horner et al., 1989; Aekatasanawan et al., 1991a; 1991b; 1991c; Russell et al., 1992; Landi and Frascaroli, 1995; Weyhrich et al., 1998; Menz Rademacher et al., 1999). The evidence showed that inbred tester with low frequency of favorable alleles at important loci gives greater genetic variance in testcrosses and should be the effective tester.

The utilization of line as tester is not new, but it was suggested previously by Horner et al. (1963) that, in recurrent selection, inbred testers were more effective than broad base testers especially for yield improvement in maize. Russell et al. (1973) evaluated yield gain from five cycles of recurrent selection in two maize populations, an OPV ‘Alph’ and the F_2 of WF9 × B7, using inbred B14 as tester. The rates of yield gain per cycle were significant for both population testcrosses. The B14 × Alph C5 yielded nearly as high as the best single-cross check, B37 × B45, and also had root and stalk lodging and maturity values that would be very acceptable for commercial use. Both populations per se also showed significant rates of yield gain per cycle.

Walejko and Russell (1977) evaluated progress in yield improvement from five cycles of recurrent selection in two OPVs, Kolkmeier and Lancaster, using inbred Hy as tester. The two populations per se had no yield gain because of inbreeding from the recombination of only five S_1 lines to form C1 populations. The program was successful in increasing frequency of favorable alleles affecting yield of the population crosses and the Hy testcrosses.

Weyhrich et al. (1998) reported progress from four cycles of recurrent selection in BS11 maize population using inbred B79 as tester. The selection method was successful in significantly improving both the population per se and the testcross performance for grain yield, stalk lodging and root lodging whereas grain moisture decreased significantly only in the population per se.

Narro et al. (2003) used SREG (site regression) to identify the best tester for discrimination among lines for formation of synthetics. Four testers used were two broad base testers (OPVs: T1 and T2) and two narrow base testers (S_3 line: T3 and single-cross S_3 hybrid: T4). The results showed that T3, the S_3 line tester, gave a high power to discriminate among lines and was the best representative of all testers, followed by T1, T4 and T2. Also, the synthetic developed with the S_3 line tester gave the highest yield and the one developed with an OPV tester gave the lowest.

C. Relative efficiency of MRRS

RRS has been proved to be a successful method for improving the performance of a cross population and to increase the heterosis between populations. Eberhart et al.

(1973) reported progress from five cycles of RRS in the BSSS and BSCB1 maize populations. The improvement in grain yield was significant in population crosses (23%) with the rate of 4.6% cycle^{-1}. Heterosis increased from 15% in C0 × C0 to 37% in C5 × C5. Conti et al. (1977) reported responses after two cycles of RRS in two local Italian maize populations designated as A and B. The linear response for grain yield in the population cross was highly significant at the rate of 7.8% cycle^{-1}. The AC2 × BC2 gave higher grain yield than the check, a commercial cross (Marano Ibrido), with highly significant. Heterosis for grain yield in population crosses increase from 5.1% in C0 to 9.5% in C2. Significant improvement in grain yield was also found in the populations per se. Besides, root lodging was greatly reduced in both populations per se.

Martin and Hallauer (1980) reported responses for grain yield from seven cycles of RRS in the BSSS and BSCB1. Grain yield of the population cross increased 175 kg ha^{-1} cycle^{-1}, but yield of the populations per se did not change significantly. Mean yield of the population crosses increased from 5,850 kg ha^{-1} in C0 to 7,070 kg ha^{-1} in C7. Midparent heterosis increased from 14.9% in C0 to 41.7% in C7.

Keeratinijakal and Lamkey (1993a) evaluated responses from 11 cycles of RRS in the BSSS and BSCB1. The response in grain yield of the population cross was 6.95% cycle^{-1}. The midparent heterosis increased from 25.44 to 76.04% from C0 to C11. For the populations per se, grain yield of BSCB1 increased 1.94% cycle^{-1}, but grain yield of BSSS did not change significantly. The selection was also effective in reducing root and stalk lodging.

The efficiency of MRRS was found to depend on base populations as well as inbred testers. After MRRS was proposed, the uses of inbred lines vs. populations as testers in reciprocal recurrent selection were investigated. Comstock (1979) compared between theoretical expectation using RRS and MRRS for multiple alleles and found that the RRS was slightly superior to MRRS. He concluded that rates of change in allele frequencies in RRS will not be more rapid when inbred lines extracted from the populations are used as testers rather than the populations themselves. He also emphasized that the critical parameter in any comparison of testers to be employed in RRS is the expectation of allele frequency change per unit of time. The suggestion by Russell and Eberhart (1975) would be a consequence of the erroneous assumption that "because of the greater variance among the testcrosses with the inbred tester, gain from selection would be greater". In terms of expectation, there is no reason to expect better results from the use of inbred tester rather than the use of population tester.

Russell et al. (1992) compared progress after three cycles of RRS and MRRS in the BS21 and BS22 maize populations using A632 and H99 as inbred testers, respectively. The RRS population cross gave significant linear gains for grain yield, whereas there were no achieved gains of yield for MRRS population cross due to the masking effects caused by dominant favorable alleles of tester H99. The improvement for lodging resistance was not achieved for BS22 × H99 because H99 contributed good resistance for root and stalk lodging to hybrids.

Menz Rademacher et al. (1999) compared responses to selection after six cycles of RRS and MRRS in the same populations used by Russell et al. (1992). They found that RRS population cross gave a greater response for grain yield (4.4% cycle^{-1}) than MRRS (1.6% cycle^{-1}). RRS was more effective than MRRS in improving grain yield in the cross population BS21 × BS22. RRS was also as effective as MRRS for improving grain yield of the populations testcrossed with the inbred testers. There was no evidence that the genetic variation for grain yield among testcrosses in MRRS was greater than RRS. They discussed that A632 (Reid Yellow Dent) was not an appropriate tester for BS21 (54% Reid Yellow Dent germplasm). The testcross of BS22 × H99 gave smaller estimate of genetic variance for grain yield and root and stalk lodging which may be due to the masking effects of the tester H99.

The efficiency of MRRS, however, was also reported in many studies. Russell and Eberhart (1975) found that one cross of elite lines derived from BSCB1(R)C5 × BSSS(R)C5 gave significantly higher yield than the best single-cross check, B37 × Oh43, with low root and stalk lodging as the check. Lambert (1984) evaluated responses of two cycles of MRRS in the BS10 and RSSSC populations grown in a high yield environment. The inbred testers used were B37 and B79 derived from BSSS and BS10, respectively. Selection was based on S_1 and testcross performance. The results showed significant response for grain yield in both populations per se and population crosses. Grain yield of BS10 and RSSSC increased from C0 to C2 for 15% cycle^{-1} and 14% cycle^{-1}, respectively. Population crosses increased 600 kg ha^{-1} cycle^{-1}. Only the population testcross of BS10 × B37 showed significant increase in grain yield. They concluded that the preliminary results from MRRS in a high yield environment appeared to be a valid approach to the improvement of populations and ultimate hybrids with high yield potential and other desirable traits.

Stojšin and Kannenberg (1994a; 1994b) studied only responses of populations per se from four cycles of MRRS in CGSynA and CGW maize populations. Inbred lines derived from each population were used as the reciprocal testers. The results showed significant increase for yield in both populations with significant increases of both ear and plant heights.

Landi and Frascaroli (1995) conducted two cycles of MRRS to develop early genotypes for a delayed-sowing crop. Two early synthetics, A and B, were used as base populations using A632 and W117 as an inbred tester, respectively. They reported that heterosis of the population cross was highly significant for grain yield and for sowing-silking interval. For grain yield of the populations per se, Synthetic A showed a moderate and nonsignificant gain per cycle whereas Synthetic B exhibited a highly significant gain per cycle. They assumed that the greater response for grain yield in Synthetic B than Synthetic A because A632 had more homozygous dominant favorable loci than W117.

D. Gene action related to MRRS

Gene action pertained to population to be improved was found to relate to kinds of recurrent selection. All procedures of reciprocal recurrent selection schemes are based on the original procedure proposed by Comstock et al. (1949) which was designed to make maximum use of general and specific combining abilities. A common feature of all procedures is improvement of populations by changing gene frequencies in a directed and complementary way, so that a wide range of different types of gene action and interactions can be retained in the crossed population (Hallauer and Miranda, 1988).

For RRS, Martin and Hallauer (1980) reported that the greatest correlation between observed and computer simulated responses from seven cycles of RRS for grain yield in the BSSS and BSCB1 was obtained from the condition of complete dominance and equal initial allele ($p = q = 0.5$) frequencies in the simulated populations. Keeratinijakal and Lamkey (1993a) indicated that RRS improved both general and specific combining ability of the populations per se. Keeratinijakal and Lamkey (1993b) partitioned the genetic response into components due to additive and dominance effects. They indicated that the response of the interpopulation cross for grain yield was primarily due to dominance effects. The selection response occurred at complementary loci with alleles in the partial to complete dominance range and with no evidence for overdominance. Improvement in the BSSS was due to both additive and dominance effects, but only dominance effects were important in the BSCB1.

In using inbred tester in recurrent selection, Hull (1945) believed that overdominant gene action was an important part of heterosis for maize grain yield. He suggested that to maximize the effectiveness of selection for overdominant loci either an inbred line or a single-cross hybrid should be used as tester. Horner et al. (1963) stated that an inbred tester can be effective in improving both specific and general combining ability. Russell et al. (1973) and Walejko and Russell (1977) found that the progress for yield in the improvement of populations with inbred testers was primarily due to general combining ability. Horner et al. (1973) found that the Inbred Tester Method (4.4% gain cycle^{-1}) was significantly more effective than the Parental Tester Method (2.4% gain cycle^{-1}) for increasing general combining ability over five cycles. They discussed that inbred testers were effective in selection for genes having additive effects because many loci of the inbred testers were homozygous recessive. Their results also indicated that dominance was important in the populations developed by the two testcross methods. Russell et al. (1973) suggested that overdominance and overdominant types of epistasis were relatively unimportant in the changes in yield potential of the populations. Walejko and Russell (1977), who conducted five cycles of recurrent selection with inbred tester, concluded that gene actions involved in yield heterosis in maize were mainly additive and partial to complete dominance.

For MRRS, Russell and Eberhart (1975) reported that most variation within each set of the elite line crosses for producing hybrids was due to general combining ability of the lines. They suggested that nonadditive gene action, other than complete dominance, is relatively unimportance. Horner et al. (1989) compared four cycles of S_2 method with TC method (MRRS) in the two maize populations, FS8A and FS8B. A line from FS8A was the tester used to evaluate S_2 lines from FS8B and vice versa. The TC method showed highly significant gains in average combining ability over both populations compared with the S_2 method (4.7 and 3.0% cycle^{-1}, respectively). The TC method also showed higher predicted yields of populations per se. The results suggested that nonadditive gene action in the overdominance range was important in these populations because in the absence of overdominance the S_2 method is expected to be more effective.

Landi and Frascaroli (1995) concluded that MRRS acted on both additive and nonadditive effects. Menz Rademacher et al. (1999) suggested that if nonadditive types of gene action except for complete dominance are not important in the expression of heterosis in maize, the use of inbred lines as testers should be as efficient as the use of populations as testers. However, if the heterosis observed in population crosses is mainly due to overdominance, pseudo-overdominance due to favorable linkage blocks, and/or epistatic interactions, the use of inbred lines as testers instead of populations should be efficient if the lines are representatives of the corresponding heterotic group.

2.4 Variety cross diallel: Gardner-Eberhart Analysis

Diallel mating designs are an important tool to obtain genetic information regarding the types of gene action for a fixed or randomly selected set of parental populations. Diallel cross is a set of paired crosses involving *n* parents. This scheme gives rise to a maximum of n^2 combinations (all possible combinations). Diallel crossing schemes and analyses have been developed for parents that range from inbred lines to broad genetic base varieties (Griffing, 1956; Gardner and Eberhart, 1966).

Hayman (1954) proposed diallel analysis in the numerical and graphical approach of n^2 progeny families produced from *n* inbred lines. The progeny families are comprised of *n* parents, F_1s and reciprocals. Hayman's approach shows that the various statistics obtained from measurements on the progeny provide estimates of the overall degree of dominance, of the relative dominance properties of the parents and of the symmetry or otherwise of the gene distribution in the lines. The graphical approach provides information about the adequacy of additive-dominance model, the average degree of dominance and characterizes parents containing most of the dominant and recessive genes (Dabholkar, 1992).

Griffing (1956) proposed a more general procedure for diallel analysis of a set of *n* inbred lines which makes provision for non-allelic interaction. Griffing (1956) suggested four methods of diallel depending on the material included in the analysis: (1) parents, F_1s and reciprocals (all n^2 combinations), (2) parents and F_1s ($n(n + 1)/2$ combinations), (3) F_1s and reciprocals ($n(n - 1)$ combinations) and (4) F_1s ($n(n - 1)/2$ combinations). Griffing (1956) stated that the proper interpretation of the combining ability effects and variance depends on the particular diallel method, the assumptions regarding the experimental material and the conditions imposed on the combining ability effects.

Gardner and Eberhart (1966) proposed a statistical genetic model for the estimation of genetic effects from the diallel cross and related populations of a fix set of *n* random-mating varieties (n ≥ 4). There are three methods of Gardner-Eberhart Analysis. Analysis I requires the evaluation of *n* parents, their F_1 crosses and inbred progeny of parents and crosses. This approach provides information on additive and dominance gene action, heterosis and inbreeding depression. This model was subsequently extended to include additive × additive epistatic effects (Eberhart and Gardner, 1966). The requirement of many kinds of populations in Analysis I limits its practical utility in applied breeding programs (Murray et al, 2003). Analysis II is useful for evaluation of *n* parents and their F_1 crosses. Variation among populations (entries) is partitioned into varieties and midparent heterosis. However, additive and dominance parameters cannot be estimated separately because they are confounded within the "variety" parameter. Heterosis is further partitioned into average, variety and specific heterosis. Analysis III includes *n* parents and their F_1 crosses as same as Analysis II. Variation among entries is partitioned into parents, parents vs. crosses and crosses. The analysis provides estimates of both variety and gca effects. Estimation of gca effects is similar to Griffing (1956) Method 4, model I (Murray et al, 2003). Both Analysis II and Analysis III provide estimates of average heterosis and specific combining ability.

Four of the mean squares of Analysis II and Analysis III are equivalent, i.e., entry and error mean squares are the same, average heterosis mean square is equal to the parents vs. crosses mean square and specific heterosis mean square is equal to the sca mean square (Gardner and Eberhart, 1966; Hallauer and Miranda, 1988). Analysis II has been reported to be superior to Analysis III because variation due to heterosis is partitioned into a single mean square which can be subdivided into three variations: variation due to average heterosis, variety heterosis and specific heterosis. All variations are due to dominance and differences in allelic frequencies between any two populations, assuming a restricted genetic model of additive and dominance effects only (Gardner and Eberhart, 1966).

Gardner-Eberhart Analysis II and Analysis III have been widely used in many studies. Eberhart (1971) conducted regional trials of two sets of variety cross diallels, Corn Belt diallel and Southern diallel, to evaluate the performance of the U.S. and semi-exotic varieties using Gardner-Eberhart Analysis II. The results showed that most of the variation among varieties and variety crosses in the two sets of diallels could be explained by the variety effects except for yield in the Southern diallel where variation due to average heterosis was substantial. Three semi-exotic Corn Belt varieties and two semi-exotic Southern varieties approach or exceed the performance of U.S. varieties and should be utilized for source of breeding populations in the U.S.

Mungoma and Pollak (1988) evaluated heterotic patterns among seven yellow-endosperm populations, among three white-endosperm populations and among all 10 populations. Diallel crosses of the 10 populations were conducted and analyzed with Gardner-Eberhart Analysis II and Analysis III. The results showed that the variation among the crosses for all traits was due primarily to gca effects. Midland × BSK(HI)C8 Syn 3 had relatively good yield and significant sca effect. BSSS(R)C10 × Mexican Dent outyielded BSSS(R)C10 × Lancaster which represents the widely used heterotic pattern Reid × Lancaster. The two crosses should be assessed for possible hybrid combinations as alternatives to the Reid × Lancaster heterotic pattern.

Mišević (1989) identified new heterotic patterns among six U.S. Corn Belt, three

Yugoslavian, two exotic and two partially exotic populations for maize breeding programs including reciprocal recurrent selection. A diallel set of the 13 populations was made and analyzed following the model of Gardner-Eberhart Analysis II and Analysis III. The results indicated that the variation in grain yield within the set of populations and population crosses was due to both additive and nonadditive genetic effects. For other traits, the variation among population crosses was primarily due to additive genetic effects.

Mišević et al. (1989) determined heterotic patterns among high oil maize populations and identified superior high oil populations for use in a recurrent selection program. Diallel crosses were made from six populations having 5 to 18% oil and analyzed by Gardner-Eberhart Analysis II and Analysis III. The results showed that population and heterosis effects were significant sources of variation among population crosses for oil percentage, grain yield and grain moisture. However, additive genetic effects were much more important than nonadditive genetic effects for oil percentage. The potential populations, RSSSC HO and ASKC24, revealed high heterosis and specific heterosis effects for grain yield and high population cross means for oil percentage and grain yield.

Moreno-Gonzalez et al. (1997) assessed the potential of four U.S. Corn Belt dent populations and four European early flint populations for the development of hybrids in the early maize growing regions of Europe. The eight populations were crosses in a diallel fashion with the use of Gardner-Eberhart Analysis II. They found that the dent populations outyielded the flint populations in both populations per se and population crosses. The average performance for grain yield of population crosses in the F × D group was not significantly higher than the D × D group, but was significantly higher than the F × F group. Also, favorable alleles for both root and stalk lodging tolerance are present in the dent populations. They concluded that the use of dent × dent hybrids is appropriate in mild summer environment.

Mickelson et al. (2001) assessed heterotic relationships among nine temperate and subtropical maize populations using diallel mating design with Gardner-Eberhart Analysis II. The study demonstrated that Population 44 had good per se performance and BSSS(R) had good performance in crosses. Also, the two populations were involved in the highest-yielding cross and the best heterotic combination.

Velasco et al. (2002) used the diallel cross with Gardner-Eberhart Analysis II to identify the best combination of field and sweet corn germplasm for improving resistance of sweet corn to corn borers. Three field corn synthetics and three sweet corn cultivars were involved in the study. The results indicated that the use of EPS6(S)C3 × Golden Bantam and EPS7(S)C3 × Stowell's Evergreen was the best choice to obtain a sweet corn heterotic pattern (Stowell's Evergreen × Golden Bantam) with improved agronomic performance and resistance to corn borers.

Doerksen et al. (2003) assessed the 12 maize populations selected via RRS, selfed-progeny recurrent selection (S) or a method combining RRS and S (COM) for changes in the genetic structure of grain yield, grain moisture, broken stalks and two associated selection indices. Gardner-Eberhart Analysis II and Analysis III were used to partition the entry sums of squares from diallel matings of the original (C0) and advanced (CA) cycle populations. The results indicated genetic improvement in both the per se and cross performance of most populations, accompanied by increasing nonadditive genetic effects in the CA at the expense of additive genetic effects. In addition, Lee et al. (2003) further partitioned grain yield by Gardner-Eberhart Analysis III to examine the genetic components of stability. They found that grain yield stability for this set of material is mostly controlled by additive genetic effects.

Reif et al. (2003) evaluated seven populations including six tropical late white maize populations and one gene pool developed by CIMMYT in a diallel scheme with Gardner-Eberhart Analysis III. The results showed that the comparison of parents vs. crosses was significant only for grain yield. The variation among the crosses was primarily because of significant gca effects whereas sca effects were not significant for any traits.

Soengas et al. (2003) searched for a flint × flint heterotic pattern as an alternative to the European flint × Corn Belt dent used in temperate areas. The diallel crosses of 10 flint maize germplasm adapted to temperate conditions were analyzed by Gardner-Eberhart Analysis II. They found no significant variety effects for grain yield among diallel populations. Only average heterosis was significant, indicating that cultivars had similar contributions to heterosis in their crosses. It is possible, however, to develop hybrids combining good yield and the typical agronomic traits of flint maize. Also, Soengas et al. (2006) analyzed diallel entries of the 10 flint maize varieties following Gardner-Eberhart Analysis II to study the performance of the flint varieties for adaptation to European Atlantic conditions. The results showed that variety and heterosis effects were significant for all traits (early vigor, days to silking and kernel moisture at harvest). They suggested that although variety effects were the most important in the inheritance of the adaptive traits, heterosis was also significant and, therefore, dominance effects were also important.

Melani and Carena (2005) identified alternative heterotic patterns for the northern Corn Belt among diallel crosses of 10 maize populations. The genotype source of variation was partitioned following Gardner-Eberhart Analysis III. They found high significance among crosses for all of the traits (grain yield, harvest grain moisture and root and stalk lodging). The comparison between parents vs. crosses was highly significant for grain yield, indicating heterosis between the populations.

2.5 North Carolina Design II

Comstock and Robinson (1948, 1952) proposed three mating designs known as North Carolina Design I, II and III. The experimental material of North Carolina designs is developed from F_2 generation as a base population. The North Carolina designs were developed to measure average degree of dominance involved in the action of genes governing quantitative characters (Comstock and Robinson, 1948; 1952, Dabholkar, 1992). Also, the designs provide the estimation of additive and dominance components of variance, the two most important genetic parameters (Singh and Chaudhary, 1979).

North Carolina Design II (NC II) or factorial design is quite different from diallel mating designs for basic features, but the two designs are similar in the genetic information provided by the designs (Hallauer and Miranda, 1988). The NC II mating design is a set of crosses between different sets of males and females, whereas the diallel designs use the same parents as both males and females in crosses. In this design, both paternal and maternal half-sibs are produced. A set of crosses in NC II design is produced by mating between randomly selected m males and f females. Each of m males is crossed to all of the f females, resulting in $m \times f$ progeny families which are evaluated by a suitable experimental design. Thus, the NC II is a case of cross-classification design. The sources of variation for males (gca), females (gca) and the interaction of males with females (sca) are interpreted (Comstock and Robinson, 1948; 1952; Singh and Chaudhary, 1979; Hallauer and Miranda, 1988; Dabholkar, 1992).

The ultimate goal of the most applied breeding programs is to obtain elite inbred lines for producing single-cross hybrids. The NC II is a scheme used to evaluate parental lines and hybrids including parental populations. Hoegemeyer and Hallauer (1976) compared between the diagonal (or tested) vs. off-diagonal (or previously untested) crosses produced from the interpopulation selected lines from BS10 and BS11 populations. The interpopulation crosses are produced by using NC II scheme to assay the effects of selection among and within full-sib families for the means of single-cross hybrid development. The results showed that the diagonal crosses averaged significantly high yield and indicated positive of nonadditive genetic effects for the yield advantage of diagonal crosses. They concluded that the selection method successfully isolated inbred lines with superior specific combining ability and general combining ability.

Lamkey and Hallauer (1986) selected 24 high- and 24 low-yielding lines per se from the BSSS population and used NC II mating scheme to produce high × high (HH), high × low (HL) and low × low (LL) single crosses. The hybrids of lines selected for yield per se were evaluated for performance. The results showed significant differences among hybrid group means for grain yield. The group means were ranked HH > HL > LL as expected under a model with partial to complete dominance. However, selection for yield of lines per se performance within groups was not related to either specific combining ability or general combining ability.

Aekatasanawan et al. (1991c) evaluated lines having high gca and high-yielding hybrids derived from Caripeno DMR(S)C5 and Suwan1(S)C10 maize populations. The 10 highest-yielding S_3 lines selected from three methods (S_1 line per se (S_1), S_1

testcrossed with low- (TC_1) and high-(TC_2) favorable gene testers) in each population were crossed to produce interpopulation hybrids using the NC II design. The results ranked $TC_1 > S_1 > TC_2$ for the methods which gave lines with high gca. The number of hybrids with significant higher yield than the check from the S_1 method were near to the TC_1 method and obviously more than the TC_2 method. They also found that the most variation in all 13 traits of the S_3 lines was attributed to general combining ability. The results indicated that additive gene action with partial to complete dominance is important in maize populations.

de la Vega and Chapman (2006) constituted a set of 16 sunflower single-cross hybrids using the NC II. The hybrids were grown in 11 environments in Argentina for applying multivariate analyses to study interactions between environment and combining abilities in hybrids. The results indicated the efficiency of two- and three-mode PCAs to study gca × E and sca × E interactions, allowing the selection of the best tester for each selection strategy (broad or specific adaptation) and showing the variability of the tested lines for adaptation and combining ability.

Rasmussen and Hallauer (2006) evaluated seven BSSS and five non-BSSS populations, including eight U.S. Corn Belt populations and four exotic maize populations selected for adaptation to temperate environments, by using the NC II design. The results indicated that maternal effects were not significant for the population crosses. Average midparent heterosis was 1.78 t ha^{-1} (34.4%) for the 35 crosses (6.96 t ha^{-1}) compared with the 12 parents (5.18 t ha^{-1}). Estimates of gca effects were significant for grain yield for all populations, but sca effects were significant for only 7 of 35 crosses. An adapted strain of Suwan 1, BS29(R)C3, seems to have the greatest potential to contribute to U.S. maize breeding programs.

CHAPTER III

MATERIALS AND METHODS

3.1 Genetic materials

Genetic materials used in this study were divided into two groups. The first group was a set of germplasms used in MRRS procedure including two populations and two inbred lines. The second group was check varieties. These genetic materials were developed by the Kasetsart University Corn Breeding Project at the National Corn and Sorghum Research Center (Suwan Farm), Inseechandrastitya Institute for Crops Research and Development, Pakchong, Nakhon Ratchasima. Details for these genetic materials are as follows:

3.1.1 Germplasms used in the selection:

3.1.1.1 Suwan1(S)C11 or SW1(S)C11 – The population was improved for grain yield and corn downy mildew resistance by 11 cycles of S_1 recurrent selection which was completed in 1987. The base population was Thai Composite #1 DMR BC_3(S)C2 or SW1(S)C0. It was a composite of 36 germplasm sources (Appendix Table 1A) and two sources of downy mildew resistance with high yield (Philippine DMR 1 and 5) (Sriwatanapongse et al., 1993; Jampatong, 1994).

3.1.1.2 Kasetsart Synthetic 6(S)C3 or KS6(S)C3 – The population was improved for grain yield and corn downy mildew resistance by three cycles of S_1 recurrent selection. KS 6 was synthesized in 1983 from 40 S_1 lines of a total of four composite varieties (Appendix Table 2A). KS 6 was developed to provide a population containing tropical germplasms which differed considerably from Suwan 1 (Jampatong, 1994).

3.1.1.3 Kasetsart Inbred Line 46 or Ki 46 – Ki 46 is a commercial inbred developed from Suwan1(S)C10 which was improved for one cycle by crossing with a low favorable gene tester. The development of Ki 46 was started in 1989. Suwan1(S)C10(HLT)C1-F_2-S_8-159-1-1-1-1 inbred line was released from the program and designated as Ki 46. It has a strong root system, high resistance to corn downy mildew, good husk cover and orange-yellow flint for color and grain type. Ki 46 gave high specific combining ability with Ki 45 which became a single-cross hybrid, Suwan 3851. Suwan Farm released Ki 46 to public and private sectors in 1997 (Aekatasanawan et al., 2001a).

3.1.1.4 Kasetsart Inbred Line 47 or Ki 47 – Ki 47 is a commercial inbred developed from KS6(S)C3. The development of Ki 47 using pedigree selection method was started in the 1990 early rainy season. The selection for corn downy mildew resistance in an artificial block was made in S_4 generation. The selected S_4 and S_6 lines were evaluated by crossing with Ki 21 and Ki 46 (inbred testers), respectively. KS6(S)C3-S_8-554-2-1-2-1 inbred line was released from the program and designated as Ki 47. It has a strong root system, high resistance to corn downy mildew, resistance to foliar diseases, excellent husk cover and orange-yellow flint for color and grain type. Ki 47 gave high combining ability, especially high specific combining ability with Ki 45 which became a single-cross hybrid, Suwan 3853. Suwan Farm released Ki 47 to public and private sectors in 2001 (Aekatasanawan et al., 2001b).

3.1.2 Check varieties:

3.1.2.1 Suwan5(S)C3 – The population was improved by S_1 recurrent selection for three cycles. Suwan 5 or Kasetsart Synthetic 5 (KS 5) was formed from 60 selected full-sib progenies of interpopulation crosses among four elite open-pollinated varieties; Suwan1(S)C9, Caripeno DMR(S)C5, Thai Composite #3 DMR(S)C5(M)C1 and Cupurico Flint Composite DMR(F)C4(S)C2, and 10 selected full-sib progenies of Amarillo Dentado (F)C5 in 1984. The proportions of five elite open-pollinated varieties were 32, 22, 17, 15 and 14%, respectively. The performance of its agronomic traits and adaptability under unfavorable and favorable environments was better than Suwan 1. It also had high plant fresh and dry weights which are suitable for corn silage. Suwan 5 was released to farmers in 1993 (Aekatasanawan et al., 1994).

3.1.2.2 Suwan5(S)C4-F_2 – The population was improved by S_1 recurrent selection for four cycles and developed to F_2 generation.

3.1.2.3 Suwan 3851 – The hybrid was developed to give a higher grain yield than that of Suwan 3504 (a single-cross hybrid check) at least 5%. Suwan 3851 is a single-cross hybrid crossed between Ki 46 and Ki 45 ([(Ki 21 × Tzi 15)-S_2 × Ki 21]-S_8-36-2-2-2). Its color and grain type are orange-yellow and semi-flint. It was released to public and private sectors in 1997 (Aekatasanawan et al., 1998).

3.1.2.4 Suwan 4452 – The hybrid was developed to give a higher grain yield than that of Suwan 3851 (a single-cross hybrid check) at least 10%. Suwan 4452 is a single-cross hybrid crossed between Ki 47 and Kei 0102 (3013-S_8-57-1) or Ki 48 (Aekatasanawan et al., 2007). It is resistant to corn downy mildew and southern corn rust. Its color and grain type are orange-yellow flint. It was released to farmers and public and private sectors since 2003 (Aekatasanawan et al., 2005).

3.1.2.5 Ki 46 – See the details in 3.1.1.3

3.1.2.6 Ki 47 – See the details in 3.1.1.4

3.2 Methods

Two cycles of MRRS were made at Suwan Farm from the 2000 late rainy season to the 2005 early rainy season. The procedures consisted of three main parts: (i) population improvement, (ii) hybrid development and (iii) inbred line development. The details are as follows:

3.2.1 Population improvement

This study was aimed to improve the two heterotic populations, Suwan1(S)C11 and KS6(S)C3, by using MRRS for use as source populations for new inbred lines. The steps and details of the improvement in two cycles were as follows:

(1) C0-S_1 Formation (2000L)

Suwan1(S)C11 and KS6(S)C3, the two base populations, were designated as AC0 and BC0, respectively. A, B and C0 represented Suwan1(S)C11, KS6(S)C3 and cycle 0 of selection, respectively. Each population was planted about 5,000 plants. Each row was 5 m long with spacings of 0.75 m between rows, and 0.25 m between hills. Plots were overplanted (two seeds per hill) and thinned to one plant per hill (at 7-14 days after emergence). Plants which had good agronomic traits were selected and self-pollinated to produce about 500 S_1 ears. After harvest, 300 S_1 ears from each population were selected based on ear aspect.

(2) C0-S_1 Testcross: AC0-S_1 × Ki 47 and BC0-S_1 × Ki 46 (2001D)

In each isolated block, the selected 300 S_1 lines were used as females and planted in single-row plots, 5 m long with spacings of 0.75 m between rows, and 0.20 m between hills. Plots were overplanted and thinned to one plant per hill. Ki 47 and Ki 46, the inbred testers for AC0 and BC0, were planted as male parents. The planting ratio was one male row to four female rows (ratio 1:4). Each inbred tester was planted with one plant per hill, spacing 0.10 m between hills in single-row plots. The female rows were detasseled and pollinated by wind-blown pollen from the adjacent male rows. At harvest, only ears from each female row were harvested and shelled in bulk within each line.

(3) C0-S_2 Line development (2001D)

The 300 S_1 lines from each population were also planted in single-row plots, 5 m long with spacings of 0.75 m between rows, and 0.20 m between hills. Plots were overplanted and thinned to one plant per hill. The lines were self-pollinated to produce S_2 generation. The S_2 ears in each line were selected based on ear aspect and shelled in bulk within each line.

After the steps (2) and (3), only 250 S_2 lines and their corresponding testcrosses from each population were selected based on line performance and ear aspect.

(4) C0-S_1 Testcross yield trial (2001L)

A total of 256 entries from each population, including the 250 testcrosses and six hybrids, was evaluated at Suwan Farm. The six hybrids included in both testcross yield trials were BIG 919 and BIG 949 from Monsanto Seeds, 30A33 from Pioneer Hi-Bred, KSX 4156, Suwan 3853 and Suwan 3851 from Suwan Farm. Among these hybrids, only Suwan 3851 was used as the check whereas others were fillers. The entries were evaluated in a 16×16 simple lattice design using single-row plots, 5 m long with spacings of 0.75 m between rows, and 0.25 m between hills. Plots were overplanted and thinned to one-plant hills for a uniform stand density of approximately 53,333 plants ha^{-1}. Conventional fertilization and weed control practices were used at the recommended application rates at Suwan Farm for optimum grain production.

Basal fertilizer 16-20-0 was broadcasted before planting at 312.5 kg ha^{-1}. One month after planting, side dressing fertilizer 46-0-0 was applied at 156.25 kg ha^{-1}. Atrazine and Stomp were mixed at the rate of 4,000 g ha^{-1} and 4,687.5 cc ha^{-1}and applied as pre-emergence herbicides.

(5) C1 Population formation: AC1 and BC1 (2002D)

From the step (4), 25 top-yielders of testcrosses in each group were selected and their corresponding S_2 lines were recombined to form their C1 populations. These populations were Suwan1(S)C11(MRRS)C1-F_1 or AC1-F_1 and KS6(S)C3(MRRS)C1-F_1 or BC1-F_1. The steps in the recombining process of each population were as follows:

Step 1: The 25 S_2 lines were planted in two-row plots, 5 m long with spacings of 0.75 m between rows, and 0.20 m between hills. Plots were overplanted and thinned to one plant per hill.

Step 2: After the 25 lines reached stages of 50% anthesis and silking, the bulk of pollens of each line was collected.

Step 3: Each line was crossed with the balanced pollens from the rest of 24 lines. Before crossing, the pollens were mixed thoroughly. Then, the 25 lines were crossed with the mixed pollens described above.

Step 4: Steps 2 and 3 were repeated two to three times until the 25 lines were intermated completely.

At harvest, ears from each line were harvested and shelled in a set of balanced seeds within each line. Consequently, there were 25 groups of F_1 seeds from each population to form each C1 population.

(6) Advanced generations of C0 and C1 populations (2002E)

The balanced F_1 seeds of the 25 groups were mixed thoroughly to form

AC1-F_1 and BC1-F_1 seeds. Each population of four original and improved populations (AC0, BC0, AC1 and BC1) was randomly mated to provide its advanced generation (AC0 $\rightarrow$ AC0#, BC0 $\rightarrow$ BC0#, AC1-F_1 $\rightarrow$ AC1-F_2 and BC1-F_1 $\rightarrow$ BC1-F_2). Each population was planted in 40-row plots, 5 m long with spacings of 0.75 m between rows, and 0.25 m between hills (approximately 840 plants population^{-1}). The 40 rows were divided into two parts. Each part consisted of 20 rows. The bulk of pollens from each part was collected and pollinated to each other. The reciprocal pollination was repeated completely. After harvest, 266-472 ears from each population were kept, except rotten ears. Then 3 kg-seeds (about 10,000 seeds) of each population were balanced from the selected ears.

(7) C0 and C1 Population diallel crosses (2002E)

The four populations used in the step (6) were planted in 10-row plots each. Each row was 5 m long with spacings of 0.75 m between rows, and 0.25 m between hills. Plots were overplanted and thinned to one plant per hill to have approximately 210 plants population^{-1}. The 10-row plot of each population was used as female. They were pollinated for a half diallel cross on the assumption of no maternal effects by using the bulk of pollens from the four populations in the step (6), except itself. After harvest, 80-135 ears from each cross were kept, except rotten ears. The six diallel crosses were AC1 × AC0, AC0 × BC0, AC0 × BC1, AC1 × BC0, AC1 × BC1 and BC1 × BC0. Then 3 kg-seeds (about 10,000 seeds) of each cross were balanced from the selected ears.

(8) C0 and C1 Population topcrosses:

(AC0, AC1) × Ki 47 and (BC0, BC1) × Ki 46 (2002E)

The four populations used in the step (6) were planted in 10-row plots each and used as female. Each row was 5 m long with spacings of 0.75 m between rows, and 0.25 m between hills. Plots were overplanted and thinned to one plant per hill to have approximately 210 plants population^{-1}. Ki 47 and Ki 46, the inbred testers for (AC0, AC1) and (BC0, BC1), were used as male. Ki 47 was planted in 44-row plot whereas Ki 46 was planted in 30-row plot. Each tester was planted with spacings of 0.75 m between rows, and 0.20 m between hills with one plant per hill. The bulk of pollens of each tester was collected and pollinated to each population. After harvest, 66-148 ears from each cross were kept, except rotten ears. Then 3 kg-seeds (about 10,000 seeds) of each cross were balanced from these ears.

(9) Progress from selection yield trial (2002L)

Yield evaluation was performed at two locations (Suwan Farm and NSWFCRC). A total of 16 entries, i.e., four populations per se from the step (6), six population crosses from the step (7), four population topcrosses from the step (8) and other two populations, was evaluated in a randomized complete block design with four replications using two-row plots. The two populations included in the yield trials were Suwan3(S)C4 and Suwan5(S)C3 from Suwan Farm. Suwan5(S)C3 was used as the check whereas Suwan3(S)C4 was a filler. Each row was 5 m long with spacings of 0.75 m between rows, and 0.25 m between hills. Plots were overplanted and thinned to one-plant hills for a uniform stand density of approximately 53,333 plants ha^{-1}. Conventional fertilization and weed control practices were used at the recommended application rates at each location for optimum grain production. For Suwan Farm, the details for practices were described in the step (4). For NSWFCRC, basal fertilizer (at 1 week) 21-0-0 was applied at 187.5 kg ha^{-1}, the 1st side dressing fertilizer (at 3 weeks) 21-0-0 was applied at 187.5 kg ha^{-1}, the 2nd side dressing fertilizer (at 5 weeks) 21-0-0 was applied at 187.5 kg ha^{-1} and the 3rd side dressing fertilizer (at 7 weeks) 21-0-0 was applied at 187.5 kg ha^{-1}. Atrazine and alaclor were applied as mixed pre-emergence herbicides at the rate of 3,125 g ha^{-1} and 5,000 cc ha^{-1}, respectively. Sevin was applied before planting as insecticide at the rate of 3,125 g ha^{-1}.

(10) C1-S_1 Formation (2002E)

The 25 groups of F_1 seeds of each C1 population from the step (5) were planted and self-pollinated to produce S_1 lines (AC1-S_1 and BC1-S_1). Each group was planted in 10-row plots, 5 m long with spacings of 0.75 m between rows, and 0.25 m between hills (approximately 5,250 plants population^{-1}). Plants which had good agronomic traits were selected and self-pollinated to produce about 30-50 S_1 ears group^{-1}. After harvest, 20-25 S_1 ears from each group were selected based on ear aspect. A total of 522 and 538 S_1 ears from AC1 and BC1 were selected, respectively.

(11) C1-S_1 Testcross: AC1-S_1 × Ki 47 and BC1-S_1 × Ki 46 (2003D)

The 522 AC1-S_1 and 538 BC1-S_1 lines were planted in an isolated block with different planting dates and used as females. The S_1 lines were planted in single 2.2 m-row plots. The planting of males (Ki 47 and Ki 46) and females and harvesting of testcrossed ears were practiced following the step (2).

(12) C1-S_2 Line development (2003D)

The 522 AC1-S_1 and 538 BC1-S_1 lines were planted in single 2.2 m-row plots. The planting, selfing and selecting for S_2 line development were practiced as mentioned in the step (3).

(13) C1-S_1 Testcross yield trial (2003E)

A total of 256 entries, including the 250 testcrosses and six hybrids, was evaluated at Suwan Farm. The six hybrids included in both testcross yield trials were

BIG 949 from Monsanto Seeds, KSX 4501, KSX 4505, KSX 4507, KSX 4452 (Suwan 4452) and Suwan 3851 from Suwan Farm. Among these hybrids, only Suwan 3851 was used as the check whereas others were fillers. The entries were evaluated as described in the step (4), except for higher plant density of 66,666 plants ha^{-1} approximately.

(14) C2 Population formation: AC2 and BC2 (2004E)

From the step (13), 25 top-yielders of testcrosses in each group were selected and their corresponding S_2 lines were recombined to form each C2 population. These populations were Suwan1(S)C11(MRRS)C2-F_1 or AC2-F_1 and KS6(S)C3(MRRS)C2-F_1 or BC2-F_1. Recombination and balanced seeds of each population were practiced as described in the step (5), except for intermating the 25 lines by balanced pollens from all of the 25 lines.

(15) Advanced generations of C0, C1 and C2 populations (2005D)

The balanced F_1 seeds of the 25 groups were mixed thoroughly to form AC2-F_1 and BC2-F_1 seeds. Each population of six original and improved populations (AC0, BC0, AC1, BC1, AC2 and BC2) was randomly mated to provide its advanced generation (AC0$\rightarrow$AC0#, BC0$\rightarrow$BC0#, AC1-$F_2$$\rightarrow$AC1-$F_3$, BC1-$F_2$$\rightarrow$BC1-$F_3$, AC2-$F_1$$\rightarrow$AC2-$F_2$ and BC2-$F_1$$\rightarrow$BC2-$F_2$). Each population was planted in 20-row plots (approximately 420 plants $population^{-1}$). The pollination was made as the same manner as the step (6). After harvest, 205-255 ears, except rotten ears from each population were kept. Then 3 kg-seeds (about 10,000 seeds) of each population were balanced from these ears.

(16) C0, C1 and C2 Population diallel crosses (2005D)

The six populations used in the step (15) were used for a half diallel cross but only five populations (AC0, AC1, AC2, BC1 and BC2) were planted. Each population was planted as female in 10-row plots approximately 210 plants. The five populations were crossed with the bulk of pollens from the six populations in the step (15), except for itself, on the assumption of no maternal effects. After harvest, 88-140 ears, except rotten ears, from each cross were kept. Fifteen crosses were obtained (AC1 × AC0, AC2 × AC0, AC0 × BC0, BC1 × AC0, BC2 × AC0, AC2 × AC1, AC1 × BC0, AC1 × BC1, BC2 × AC1, AC2 × BC0, AC2 × BC1, AC2 × BC2, BC1 × BC0, BC2 × BC0 and BC2 × BC1). The 3 kg-seeds (about 10,000 seeds) of each cross were balanced from these ears.

(17) C0, C1 and C2 Population topcrosses:

(AC0, AC1, AC2) × Ki 47 and (BC0, BC1, BC2) × Ki 46 (2005D)

Ki 47 and Ki 46, the inbred testers for (AC0, AC1, AC2) and (BC0, BC1, BC2), were used as female on the assumption of no maternal effects, respectively. Each tester was planted in five-row plots cross^{-1} (approximately 130 plants). Ki 47 and Ki 46 were crossed with the bulk of pollens of 100 plants from each population of the (AC0, AC1, AC2) and (BC0, BC1, BC2), respectively, from the step (15). After harvest, 40-85 ears, except rotten ears from each cross were kept. Then 3 kg-seeds (about 10,000 seeds) of each cross were balanced from these ears.

(18) Progress from selection yield trial (2005E)

Yield evaluation was performed at two locations (Suwan Farm and NSWFCRC). A total of 30 entries, i.e., six populations per se from the step (15), 15 population crosses from the step (16), six population topcrosses from the step (17) and other three populations, was evaluated in a 5 × 6 triple rectangular lattice design using four-row plots. The other three populations were Suwan3(S)C4, Suwan1(S)C12-F_3 and Suwan5(S)C4-F_2 from Suwan Farm. Among these populations, Suwan5(S)C4-F_2

was used as the check whereas others were fillers. Plot size, spacing, and fertilizer and herbicide application were practiced as described in the step (9), except for fertilization and weed control practices at NSWFCRC. For NSWFCRC in this season, basal fertilizer (at 1 week) 15-15-15 was applied at 187.5 kg ha^{-1}, the 1^{st} side dressing fertilizer (at 4 weeks) 21-0-0 was applied at 187.5 kg ha^{-1}, the 2^{nd} side dressing fertilizer (at 7 weeks) 46-0-0 was applied at 187.5 kg ha^{-1}. Atrazine and alaclor were applied as mixed pre-emergence herbicides at the rate of 3,125 g ha^{-1} and 5,000 cc ha^{-1}, respectively.

3.2.2 Hybrid development

This study was aimed to develop high-yielding single-cross hybrids from the lines extracted from the improved populations. Single-cross hybrids obtained from the program were: (i) testcross hybrids from A lines × Ki 47, (ii) testcross hybrids from B lines × Ki 46, and (iii) interpopulation hybrids (A lines × B lines). The steps and details of hybrid development in two cycles were as follows:

(1) C0-S_4 Lines × tester: (2002E)

25 AC0-S_4 × Ki 47 and 25 BC0-S_4 × Ki 46

The 25 S_4 lines from each population, which corresponded to the lines used in the step (5) in section 3.2.1 Population improvement, were crossed with inbred tester. The process made 25 testcross hybrids from each population which was a total of 50 C0-S_4 testcross hybrids. Each line was planted in two-row plots, 5 m long with spacings of 0.75 m between rows, and 0.20 m between hills with one plant per hill. Each line from AC0 and BC0, designated as females, were crossed with the bulk of pollens of Ki 47 and Ki 46 (from the plot of inbred testers in the step (8) in section 3.2.1 Population improvement), respectively. At harvest, ears from each female row were saved and shelled in bulk within each line.

(2) C0-S_4 Lines factorial crosses: 10 AC0-S_4 × 10 BC0-S_4 (2002E)

From the C0-S_1 Testcross yield trial (2001L) in the step (4) in section 3.2.1 Population improvement, 10 testcrosses which gave the top-yield ranking in each group were selected and their corresponding S_4 lines were used to make a set of factorial crosses between the 10 lines from each population. The process made 100 C0-S_4 interpopulation hybrids. Each line was planted in 10-row plots, 5 m long with spacings of 0.75 m between rows, and 0.20 m between hills with one plant per hill. Each line from AC0 was crossed with the 10 lines from BC0. The ears of each cross were shelled in bulk.

(3) Hybrid yield trial (2002L)

Yield evaluation of C0 testcross hybrids and C0 interpopulation hybrids was performed at two locations (Suwan Farm and NSWFCRC). A total of 156 entries, i.e., 25 AC0-S_4 testcross hybrids, 25 BC0-S_4 testcross hybrids, 100 C0-S_4 interpopulation hybrids and six hybrids, was evaluated in a 12 × 13 simple rectangular lattice design using two-row plots. The six hybrids included in the yield trials were BIG 949 from Monsanto Seeds, 30A30 from Pioneer Hi-Bred, KSX 4451, KSX 4452 (Suwan 4452), KSX 4453 and Suwan 3851 from Suwan Farm. Among these hybrids, only Suwan 3851 was used as the check whereas others were fillers. Each row was 5 m long with spacings of 0.75 m between rows, and 0.25 m between hills, approximately 53,333 plants ha^{-1}. Conventional fertilization and weed control practices were used at the recommended application rates at each location for optimum grain production (see the details of practices in the step (9) in section 3.2.1 Population improvement).

(4) C0 and C1-S_3 Lines × tester (2005D)

The selected C0 testcross hybrids were reproduced to evaluate together with C1 testcross hybrids in the same experiment.

1. 10 AC0-S_3 × Ki 47 and 10 BC0-S_3 × Ki 46

From the combined analysis of the Hybrid yield trial (2002L) in the step (3), 10 testcross hybrids from AC0 and 10 testcross hybrids from BC0 were selected. The hybrids gave the top-yield ranking in each hybrid group. Their corresponding S_3 lines were used to reproduce the testcross hybrids. The process made 10 testcross hybrids from each population which was a total of 20 C0-S_3 testcross hybrids. The lines were planted in single-row plots, 5 m long with spacings of 0.75 m between rows, and 0.20 m between hills with one plant per hill. Each line from AC0 and BC0, designated as females, were crossed with the bulk of pollens of Ki 47 and Ki 46 (from the plot of inbred testers in the step (17) in section 3.2.1 Population improvement), respectively. At harvest, ears from each female row were saved and shelled in bulk within each line.

2. 25 AC1-S_3 × Ki 47 and 25 BC1-S_3 × Ki 46

The 25 S_3 lines from each population, which corresponded to the lines used in the step (14) in section 3.2.1 Population improvement, were crossed with the corresponding inbred testers. The process made 25 testcross hybrids from each population which was a total of 50 C1-S_3 testcross hybrids. The lines were planted in single-row plots, 5 m long with spacings of 0.75 m between rows, and 0.20 m between hills with one plant per hill. Each line from AC1 and BC1, designated as females, were crossed with the bulk of pollens of Ki 47 and Ki 46 (from the plot of inbred testers in the step (17) in section 3.2.1 Population improvement), respectively. At harvest, ears from each female row were saved and shelled in bulk within each line.

(5) C0 and C1-S_3 Lines factorial crosses (2005D)

The selected C0 interpopulation hybrids were reproduced to evaluate together with C1 interpopulation hybrids in the same experiment.

1. C0-S_3 Lines factorial crosses

From the combined analysis of the Hybrid yield trial (2002L) in the step (3), 10 interpopulation hybrids which gave the top-yield ranking in the hybrid group were selected. Their corresponding S_3 lines including four AC0-S_3 and six BC0-S_3 were used to reproduce the interpopulation hybrids. The process made a total of 10 C0-S_3 interpopulation hybrids. The four AC0-S_3 lines were designated as females and planted in single-row plots cross^{-1}, 5 m long with spacings of 0.75 m between rows, and 0.20 m between hills with one plant per hill. The six BC0-S_3 lines were designated as males and planted in single-row plots with the same spacing as the AC0-S_3 lines. The ears of each cross were shelled in bulk.

2. C1-S_3 Lines factorial crosses: 10 AC1-S_3 × 10 BC1-S_3

From the step (13) in section 3.2.1 Population improvement, 10 testcrosses which gave the top-yield ranking in each group were selected and their corresponding S_3 lines were used to make a set of factorial crosses between the 10 lines from each population. The process made 100 C1-S_3 interpopulation hybrids. Each line of AC1 was designated as female and planted in 10-row plots, 5 m long with spacings of 0.75 m between rows, and 0.20 m between hills with one plant per hill. Each line of BC1 was designated as male and planted in three-row plots with the same spacing as the plot of AC1 lines. Each line of AC1 was crossed with the 10 lines of BC1. The ears of each cross were shelled in bulk.

(6) C0-S_8 Hybrids (2005D)

The 10 C0 hybrids consisted of five AC0 testcross hybrids, two BC0 testcross hybrids and three C0 interpopulation hybrids which gave the top-yield ranking from the combined analysis of the Hybrid yield trial (2002L) in the step (3) were selected. Their corresponding S_8 lines including seven AC0-S_8 and four BC0-S_8 were used to make 10 C0-S_8 hybrids. Each line was planted in two-row plots, 5 m long with spacings of 0.75 m between rows, and 0.20 m between hills with one plant per hill. The bulk of pollens of Ki 47 and Ki 46 came from the step (17) in section 3.2.1 Population improvement. The ears of each cross were shelled in bulk.

(7) Hybrid yield trial (2005E)

Yield evaluation of C0 and C1 hybrids was performed at two locations (Suwan Farm and NSWFCRC). A total of 196 entries, i.e., 10 AC0-S_3 testcross hybrids, 10 BC0-S_3 testcross hybrids, 25 AC1-S_3 testcross hybrids, 25 BC1-S_3 testcross hybrids, 10 C0-S_3 interpopulation hybrids, 100 C1-S_3 interpopulation hybrids, 10 C0-S_8 hybrids and six hybrids, was evaluated in a 14×14 simple lattice design using two-row plots. The six hybrids included in the yield trials were NK 40 from Syngenta Seeds, PAC 999 (Pacific 903) from Pacific Seeds, BIG 919 from Monsanto Seeds, DK 888 (CP 888) from Charoen Seeds (C.P.), KSX 4601 and Suwan 4452 from Suwan Farm. Among these hybrids, only Suwan 4452 was used as the check whereas others were fillers. Each row was 5 m long with spacings of 0.75 m between rows, and 0.20 m between hills, approximately 66,666 plants ha^{-1}. Conventional fertilization and weed control practices were used at the recommended application rates at each location for optimum grain production (see the details of practices in the step (18) in section 3.2.1 Population improvement).

3.2.3 Inbred line development

This study was aimed to develop inbred lines with high general combining ability (gca) and/or high specific combining ability (sca) and high yield from the improved populations derived from the MRRS procedure. Pedigree selection method was used for line development. Lines were selected based on testcross performance. The steps and details of line development in two cycles were as follows:

(1) C0-S_1 Line development (2000L)

This step was the same step as the step (1) in section 3.2.1 Population improvement as described above. The 300 S_1 lines from each population (AC0 and BC0) were selected.

(2) C0-S_2 Line development (2001D)

This step was the same step as the step (3) in section 3.2.1 Population improvement as described above. The 300 S_2 lines from each population were produced.

(3) C0-S_3 Line development (2001L)

The 250 S_2 lines from each population selected from the steps (2) and (3) in section 3.2.1 Population improvement were planted in single-row plots. The rows were 5 m long with spacings of 0.75 m between rows, and 0.20 m between hills. Plots were overplanted and thinned to one plant per hill. The lines were self-pollinated to produce S_3. The S_3 ears in each line were selected based on ear aspect and shelled in bulk within each line.

(4) C0-S_4 Line development (2002D)

Only 100 corresponding S_3 lines of the 100 testcrosses which gave a top-yield ranking in each group from the step (4) in section 3.2.1 Population improvement were maintained (including 25 corresponding lines used in the step (5) in section 3.2.1

Population improvement). The lines were self-pollinated to produce S_4. The S_4 ears in each line were selected based on ear aspect and shelled in bulk within each line. Then, only 76 S_4 lines from each population were selected from line performance.

(5) C0-S_5 Line development (2002E)

The 76 S_4 lines from each population were self-pollinated to produce S_5. The S_5 ears in each line were selected based on ear aspect and shelled in bulk within each line.

(6) Inbred yield trial (2002L)

Yield evaluation of C0-S_5 lines was performed at two locations (Suwan Farm and NSWFCRC). A total of 56 entries, i.e., 25 AC0-S_5 and 25 BC0-S_5 (which corresponding respectively to the lines used to form AC1 and BC1 in the step (5) in section 3.2.1 Population improvement) and six inbred lines, was evaluated in a 7×8 triple rectangular lattice design using two-row plots. The six inbred lines included in the yield trials were Kei 0101, Kei 0102 or Ki 48, Ki 44, Ki 45, Ki 46 and Ki 47 from Suwan Farm. Among these inbred lines, both Ki 46 and Ki 47 were used as checks whereas others were fillers. Each row was 5 m long with spacings of 0.75 m between rows, and 0.20 m between hills, approximately 66,666 plants ha^{-1}. Conventional fertilization and weed control practices were used at the recommended application rates at each location for optimum grain production (see the details for practices in the step (9) in section 3.2.1 Population improvement).

(7) C0-S_6 Line development (2002L)

The 76 S_5 lines from each population were self-pollinated to produce S_6. The S_6 ears in each line were selected based on ear aspect and shelled in bulk within each line.

(8) C0-S_7 Line development (2003D)

The 76 S_6 lines from each population were self-pollinated to produce S_7. The S_7 ears in each line were selected based on ear aspect and shelled in bulk within each line.

(9) C0-S_8 Line development (2003L)

The 76 S_7 lines from each population were self-pollinated to produce S_8. The S_8 ears in each line were selected based on ear aspect and shelled in bulk within each line.

(10) C1-S_1 Line development (2002E)

This step was the same step as the step (10) in section 3.2.1 Population improvement as described above. The 522 and 538 S_1 ears for AC1 and BC1 were maintained.

(11) C1-S_2 Line development (2003D)

This step was the same step as the step (12) in section 3.2.1 Population improvement as described above. The 522 AC1-S_2 and 538 BC1-S_2 lines were produced.

(12) C1-S_3 Line development (2004E)

A total of 100 S_2 lines from each population was maintained. The lines were the corresponding lines of the 100 testcrosses which gave a top-yield ranking in each yield trial in the step (13) in section 3.2.1 Population improvement. The lines were self-pollinated to produce S_3. The S_3 ears in each line were selected based on ear aspect and shelled in balanced seeds within each line.

(13) C1-S_4 Line development (2005D)

The 100 S_3 lines from each population were self-pollinated to produce S_4.

The S_4 ears in each line were selected based on ear aspect and shelled in balanced seeds within each line.

(14) Selfing S_3 of the selected lines from C0 and C1 (2004E)

Seed quantity of the selected lines from C0 and C1 were increased for testing in the step (16): Inbred yield trial (2005E).

1. 13 AC0-S_3 and 10 BC0-S_3

From the combined analysis of the Hybrid yield trial (2002L) in the step (3) in section 3.2.2 Hybrid development, 10 testcross hybrids from AC0, 10 testcross hybrids from BC0 and 10 interpopulation hybrids were selected. The hybrids gave the top-yield ranking in each hybrid group. The corresponding lines of the selected hybrids, 13 AC0-S_2 and 10 BC0-S_2, were self-pollinated to produce S_3. The S_3 ears in each line were selected based on ear aspect and shelled in balanced seeds within each line.

2. 10 AC1-S_3 and 10 BC1-S_3

Ten corresponding S_2 lines of the 10 testcrosses which gave the top-yield ranking in each yield trial from the C1-S_1 Testcross yield trial (2003E) in the step (13) in section 3.2.1 Population improvement were self-pollinated to produce S_3. The S_3 ears in each line were selected based on ear aspect and shelled in balanced seeds within each line.

(15) Selfing S_4 of the selected lines from C0 and C1 (2005D)

The selected lines from the C0 and C1 populations (13 AC0-S_3, 10 BC0-S_3, 10 AC1-S_3 and 10 BC1-S_3) were self-pollinated to produce S_4. Each line was planted in two-row plots, 5 m long with spacings of 0.75 m between rows, and 0.20 m between hills with one plant per hill. The S_4 ears in each line were selected based on ear aspect and shelled in balanced seeds within each line.

(16) Inbred yield trial **(2005E)**

Yield evaluation of the selected C0 lines and C1 lines was performed at two locations (Suwan Farm and NSWFCRC). A total of 90 entries, i.e., 13 AC0-S_4, 10 BC0-S_4, 25 AC1-S_4, 25 BC1-S_4, seven AC0-S_8, four BC0-S_8 and six inbred lines, was evaluated in a 9×10 simple rectangular lattice design using two-row plots. The six inbred lines included in the yield trials were Kei 0102 or Ki 48, Kei 0303, Kei 0301, Ki 45, Ki 46 and Ki 47 from Suwan Farm. Among these inbred lines, both Ki 46 and Ki 47 were used as checks whereas others were fillers. Each row was 5 m long with spacings of 0.75 m between rows, and 0.20 m between hills, approximately 66,666 plants ha^{-1}. Conventional fertilization and weed control practices were used at the recommended application rates at each location for optimum grain production (see the details for practices in the step (18) in section 3.2.1 Population improvement).

(17) C1-S_5 Line development **(2005E)**

The 100 S_4 lines from each population were self-pollinated to produce S_5. The S_5 ears in each line were selected based on ear aspect and shelled in balanced seeds within each line.

Breeding schemes for the modified reciprocal recurrent selection program and for the part of population improvement are shown in Figures 3.1 and 3.2, respectively.

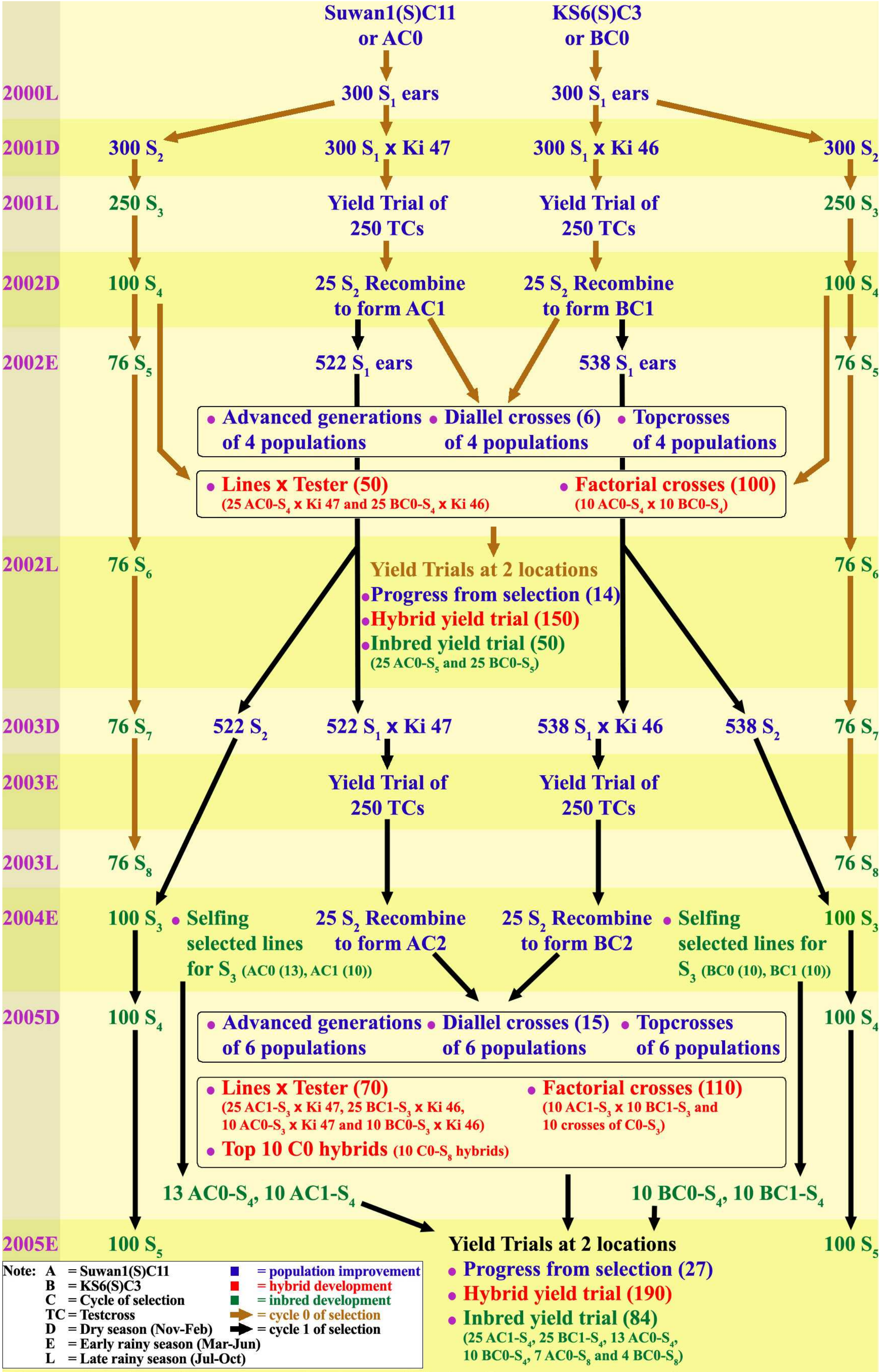


Figure 3.1 Breeding scheme for the modified reciprocal recurrent selection program.

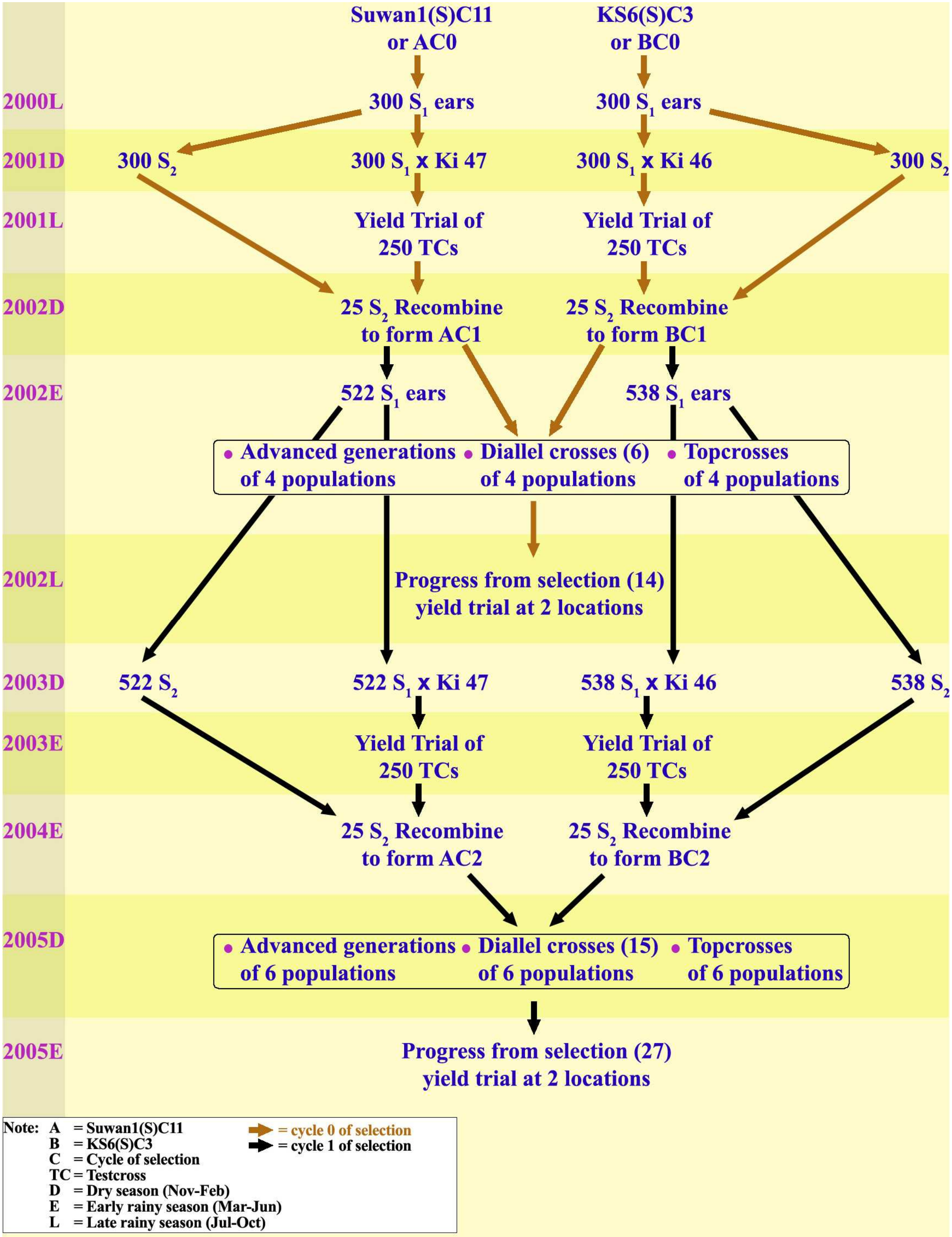


Figure 3.2 Breeding scheme for the part of population improvement.

3.3 Locations of experiment

Testing of populations, inbred lines and single-cross hybrids were conducted at two locations, i.e., Nakhon Ratchasima and Nakhon Sawan. The provinces are in major areas in the Corn Belt of Thailand. The planted areas were in the National Corn and Sorghum Research Center, Nakhon Ratchasima and Nakhon Sawan Field Crops Research Center, Nakhon Sawan. Details of the two stations are as follows:

3.3.1 National Corn and Sorghum Research Center (NCSRC; Suwan Farm) – Suwan Farm is located on Mittraphap Road, Amphoe Pakchong, Nakhon Ratchasima, Thailand, about 150 kilometers up Northeast from Bangkok. It has a latitude of 14.5°North and a longitude of 101°East with 360 m above sea level. The soil characteristic at the station is in a great soil group of Reddish Brown Lateritic soils in Pak Chong series. It is well-drained clay loam with reddish brown color and medium to low pH. The climates at the station are as follows: average temperature 30°C, average lowest temperature 14°C, average highest temperature 33°C, fresh breeze through year, average relative humidity 85% and annual rainfall of about 1,000-1,200 mm with two peaks of heavy rain (Inseechandrastitya Institute for Crops Research and Development, Online, 2006).

3.3.2 Nakhon Sawan Field Crops Research Center (NSWFCRC) – NSWFCRC is located on Phaholyothin Road, Amphoe Tak-Fa, Nakhon Sawan, Thailand, about 200 kilometers up North from Bangkok (Nakhon Sawan Field Crops Research Center, 2002). The soil characteristic of the planted area is in a great soil group of Rendzinas in Takhli series. The surface soil is black, loamy and considerably thick. The sub soil is marl. The pH of soil is high (7.7-7.8) (Grudloyma, personal communication, 2001; Grudloyma, personal communication, 2004).

3.4 Collection of data

In yield trial, data for agronomic traits were collected for seedling vigor, days to 50% anthesis and silking, plant and ear heights, stalk and root lodging, foliar diseases, husk cover, plant and ear aspects, number of harvested plants, number of total ears, number of rotten ears, ears plant^{-1}, field weight, grain weight, grain type and color, grain moisture, grain shelling and grain yield. In addition, 100-seed weight was also collected for inbred yield trials. Corn borer infestation in the 2005E caused to collect data for insect damage in the progress from selection yield trial (2005E) and hybrid yield trial (2005E). The instructions for collecting data on various traits of maize by CIMMYT (1985) were followed. A brief description of each trait is provided as follows:

1. Seedling vigor (score 1-5): Data on this trait was taken at 7-14 days after planting or before thinning. For each plot, characters such as uniformity of plants, disease and insect damage, and vigor of seedlings was rated on a scale of 1 to 5, where 1 is the best and 5 is the poorest.

2. Days to 50% anthesis and silking (d): To record (i) the number of days from planting until 50% of the plants in a plot had pollen shedding and (ii) the number of days from planting until 50% of the plants in a plot had silk extruding.

3. Plant and ear heights (cm): For random 10 competitive plants in each plot, both plant and ear heights were measured in centimeters from the plant base to the node of flag leaf and to the node bearing the uppermost ear for plant and ear heights, respectively. Plant and ear heights can be measured any time between 2 and 3 weeks after flowering until just prior to harvest.

4. Number of stalk lodging: Data on stalk lodging was taken late in the season just before harvest. The number of plants with stalks broken below the ears but not

above the ears in each plot was recorded, and then, convert the data to % stalk lodging. There may be some weak plants that have poor stalk quality, but which have not yet lodged. To identify these push the stalks gently. Plants which then fall over are counted as stalk-lodged plants.

$$\text{\% Stalk lodging} = \frac{\text{number of stalk lodging}}{\text{number of harvested plants}} \times 100$$

5. Root lodging (score 1-5): Data on root lodging was taken late in the season just before harvest. For each plot, plants that were leaning 30 degrees (°) or more from the perpendicular at the base of the plant where the root zone starts were rated on a scale of 1 to 5, where 1 indicates no plants leaning 30° and 5 indicates plants all leaning 30° or more.

6. Foliar diseases (score 1-5): To get an accurate rating of disease severity, notes were taken on damage late in the growing season at the stay green stage before the leaves begin turning brown. The damage in each plot concentrating on the diseases that were important in each location and season was rated. The diseases were southern corn leaf blight or Maydis leaf blight (*Bipolaris maydis* (Nisik.) Shoemaker or *Helminthosporium maydis* Nisik.), northern corn leaf blight or Turcicum leaf blight (*B. turcica* (Pass.) Shoemaker or *H. turcicum* Pass.), southern rust (*Puccinia polysora* Underw.), etc. Infection by the foliar disease was rated on a scale of 1 to 5, where 1 indicates no diseases and 5 indicates very heavy infection. Record the score in whole numbers or in halves.

7. Husk cover (score 1-5): For each plot, husk cover was rated on the 1 to 5 scale described below at stay green stage (1-3 weeks before harvest) when ears were

fully developed and the husk was drying down.

1 = Excellent: Husk tightly covers ear tip and extends beyond it.

2 = Fair: Covers ear tip tightly.

3 = Exposed tip: Loosely covers ear up to its tip.

4 = Grain exposed: Husk leaves do not cover the ear adequately, leaving its tip somewhat exposed.

5 = Completely unacceptable: Poor husk cover, tips clearly exposed.

8. Plant aspect (score 1-5): Data on this trait was taken at the stay green stage, when plants were still green and the ears were fully developed. For each plot, characters such as plant and ear heights, uniformity of plants, disease and insect damage, and lodging were rated on a scale of 1 to 5, where 1 is the best and 5 is the poorest.

9. Ear aspect (score 1-5): After harvest, but before taking a sample for moisture determination, ears in each plot for characters such as disease and insect damage, ear size, grain filling, grain type and color, and uniformity of ears were rated on a scale of 1 to 5, where 1 is the best and 5 is the poorest.

10. Number of harvested plants: The number of plants in the two center rows of each four-row plot or the number of plants per two-row plot at harvest, regardless whether plants bear one ear, two ears, or were barren were counted.

11. Number of total ears: The total number of ears harvested in each plot was recorded, excluding secondary ears that were extremely small.

12. Number of rotten ears: The number of ears in each plot which had the incidence of ear and kernel rots caused by *Diplodia* spp., *Fusarium* spp., *Gibberella* spp., etc. for 20% infected kernels or more was recorded, and then, convert the data to % rotten ears.

$$\% \text{ Rotten ears} = \frac{\text{number of rotten ears}}{\text{number of total ears}} \times 100$$

13. Ears plant^{-1} (%): The percentage of ears plant^{-1} in each plot was calculated using the formula illustrated below.

$$\% \text{ Ears plant}^{-1} = \frac{\text{number of total ears}}{\text{number of harvested plants}} \times 100$$

14. Field weight (kg plot^{-1}): After harvesting all plants in each plot, the field weight of ears with cobs was recorded in kilograms to two decimal place. At harvest, grain moisture content was in a range of 20-30% with full expression of stalk and root lodging and of differences among families in ear rots.

15. Grain weight (kg plot^{-1}): For the same plot whose field weight was recorded, the ears were shelled and recorded the grain weight in kilograms to two decimal place.

16. Grain type and color: Grain type together with grain color of ears in each plot such as OYF (orange-yellow flint), YOF (yellow-orange flint), OYSF (orange-yellow semi-flint), O$\hat{Y}$F-SF (orange-yellow flint and semi-flint with yellow cap; $\hat{Y}$ = the top of grain is yellow), ORF (orange-red flint), etc. were recorded.

17. Grain moisture (%): For the same plot whose grain weight was recorded, a sample of mixed grains for 100 g or 250 g was taken depended on the instruction of moisture meter. The moisture percentage in the grain with one or two decimal place was determined.

18. Grain shelling (%): The grain shelling percentage in each plot was calculated from the formula illustrated below.

$$\text{\% Grain shelling} = \frac{\text{grain weight}}{\text{field weight}} \times 100$$

19. Grain yield (kg ha^{-1}): Grain yield in each plot in kg ha^{-1} at 15% grain moisture was calculated from the formula illustrated below.

$$\text{Grain yield (kg ha}^{-1}\text{)}$$

$$= \frac{\text{field weight} \times (100 - \text{\% grain moisture}) \times \text{\% grain shelling} \times 10{,}000}{85 \times \text{harvested area} \times 100}$$

Harvested area = No. of rows × ((row length + distance between plant hills) × distance between rows)

20. 100-Seed weight (g): This data was collected only for inbred yield trials. After shelling in each plot, five samples of 100 kernels were taken to measure seed weight in grams to two decimal place and calculated at 15% grain moisture.

$$\text{100-Seed weight (g)} = \frac{100 - \text{\% grain moisture}}{100 - 15} \times \text{100-seed weight}$$

21. Insect damage: The damage was rated on a scale of 1 to 5, where 1 indicates no damage and 5 indicates very heavy infestation. The score only in whole numbers and list the pest's scientific name were recorded. This trait was focused only on corn borer because of the heavy infestation of Asian corn borer (*Ostrinia furnacalis* (Guenée)) in the 2005 early rainy season. The number of infested plants and rating score of Asian corn borer in each plot were recorded in the progress from selection yield trial (2005E) whereas only rating score of the corn borer was recorded in the hybrid yield trial (2005E).

3.5 Statistical procedure and analysis

3.5.1 Yield trials

In this study, a number of designs including simple lattice design, simple rectangular lattice design, triple rectangular lattice design and randomized complete block design were used where appropriated. Analyses of variance for individual location were done by using PROC LATTICE and PROC ANOVA of SAS version 9.0, respectively (SAS Institute, 2002).

The combined analysis of variance for data from lattice design combined across two locations was made using entry means adjusted for block effects from each individual location analysis and using the following linear model:

$$X_{ijk} = \mu + E_i + T_j + ET_{ij} + e_{ijk}$$

where: X_{ijk} = the ijkth observation;

μ = the overall mean;

E_i = the effect of the ith location;

T_j = the effect of the jth entry;

ET_{ij} is the interaction effect between the ith location and the jth entry; and e_{ijk} (pooled error) is the error effect associated with ij(k)th observation.

In the combined data analysis, entries, locations and the entry × location interaction were considered as random sources of variation. F-tests were computed to determine significance among different sources of variation and their partitioned effects within the combined analysis. The entry × location interaction term was used to test both the location and the entry sources of variation. Entry × location interaction partitioned effects were used to test the corresponding partitioned entry effects. A pooled error mean squares term was used to test the entry × location interaction and the interaction's partitioned effects. Calculation of the pooled error mean squares term was the sum of intra-block error mean squares (E_e) or effective error mean squares (E_e') from each location and divided by the number of locations. Degrees of freedom (df) for pooled error was the sum of error df from each location.

3.5.2 Gardner-Eberhart Analysis II and Analysis III

The data of populations per se and population diallel crosses from each cycle of selection (data from the progress from selection yield trial 2002L and 2005E; the step (9) and (18) in section 3.2.1 Population improvement) were also analyzed to obtain information on inheritance according to Gardner-Eberhart Analysis II and Analysis III (Gardner and Eberhart, 1966). The linear models for Gardner-Eberhart Analysis II are as follows:

1. $Y_{ij} = u_v + ½(v_i + v_j) = (B'G)_1$
2. $Y_{ij} = u_v + ½(v_i + v_j) + r\bar{h} = (B'G)_2$
3. $Y_{ij} = u_v + ½(v_i + v_j) + r\bar{h} + r(h_i + h_j) = (B'G)_3$
4. $Y_{ij} = u_v + ½(v_i + v_j) + r\bar{h} + r(h_i + h_j) + rs_{ij} = (B'G)_4$

In these models: $r = 0$ where $i = j$, $r = 1$ where $i \neq j$; and

$$\sum_i v_i = {}_i h_i = \sum_{i \neq j} s_{ij} = 0$$

The 4th linear model is a complete model.

where: Y_{ij} = the mean of a trait obtained from the cross between parental varieties i^{th} and j^{th};

u_v = the mean of all parental varieties included;

v_i, v_j = the variety effects of the parental varieties i^{th} and j^{th}, respectively;

$\bar{h}$ = the average heterosis of all crosses (or the mean of the difference between parents and their crosses);

h_i, h_j = the variety heterosis of the parental varieties i^{th} and j^{th}, respectively (measured from the deviation from $\bar{h}$);

and s_{ij} = the specific heterosis of the cross ij^{th} (measured from the deviation from $\bar{h}$).

Analysis II was used to estimate the following genetic effects: variety effect (v_i), heterosis effect (h_{ij}), average heterosis ($\bar{h}$), variety heterosis (h_i) and specific heterosis (s_{ij}). These parameters were described by Gardner (1967). The variety effect (v_i) is the difference between the mean of a parent per se and the mean of all parents, and is usually used to provide information of importance of additive genetic effects. The heterosis effect (h_{ij}) is the heterosis parameter in the cross involving population i and j, which arises as consequence of differences in gene frequencies in two populations and dominance of more favorable alleles. The average heterosis ($\bar{h}$) contributed by a particular set of parents used in crosses is the difference between the mean of all crosses and the mean of all parents. The variety heterosis (h_i) is the contribution to heterosis by population i in its crosses measured as a deviation from average heterosis. The specific heterosis (s_{ij}) occurs when populations i and j are mated and measures the deviation between the observed performance of the specific cross and its expected performance based on the v_i, $\bar{h}$ and h_i effects.

The total sum of squares for population means of Gardner-Eberhart Analysis II are subdivided and shown in Table 3.1.

Table 3.1 Sum of squares of n parents and their n(n − 1)/2 variety crosses for variety and heterosis effects for Gardner-Eberhart Analysis II (Gardner and Eberhart, 1966).

Source of variation	df	Sum of squares
Populations	[n(n + 1)/2] − 1	S'
Varieties (v_i)	n − 1	$S_1' = (B'G)_1 - CF$
Heterosis (h_{ij})	n(n − 1)/2	$S_2' = (B'G)_4 - (B'G)_1$
Average heterosis ($\bar{h}$)	1	$S_{21}' = (B'G)_2 - (B'G)_1$
Variety heterosis (h_i)	n − 1	$S_{22}' = (B'G)_3 - (B'G)_2$
Specific heterosis (sca; s_{ij})	n(n − 3)/2	$S_{23}' = (B'G)_4 - (B'G)_3$

Gardner-Eberhart Analysis III was performed to obtain general combining ability (g_i) and specific combining ability (s_{ij}) effects. The linear models for Analysis III are as follows:

$$Y_{ii} = u_v + v_i$$

and
$$Y_{ij} = u_c + g_i + g_j + s_{ij}$$

where: Y_{ii} = the mean of a trait obtained from the parental variety i^{th};

u_v = the mean of all parental varieties included;

v_i = the variety effects of the parental variety i^{th};

Y_{ij} = the mean of a trait obtained from the cross between parental varieties i^{th} and j^{th};

u_c = the mean of all crosses in the diallel set;

g_i, g_j = the general combining ability effect of parental varieties i^{th} and j^{th}, respectively (or the variety effect in crosses);

and s_{ij} = the specific combining ability effect of parental varieties i^{th} and j^{th}.

The sums of squares for crosses and its subdivision into general and specific combining ability can be done according to Griffing's (1956) method 4 model 1 or by the general least squares procedure indicated by the model for crosses, using the restrictions $\sum_{i} g_i = 0$ and $\sum_{i \neq j} s_{ij} = 0$ for each j.

The sum of squares for Gardner-Eberhart Analysis III are shown in Table 3.2.

Table 3.2 Sum of squares of n parents and their n(n – 1)/2 variety crosses for general and specific combining ability for Gardner-Eberhart Analysis III (Gardner and Eberhart, 1966).

Source of variation	**df**	**Sum of squares**
Varieties	n – 1	S_1''
Varieties vs. Crosses	1	S_2''
Crosses	[n(n – 1)/2] – 1	S_3''
General combining ability (g_i)	n – 1	S_{31}''
Specific combining ability (s_{ij})	n(n – 3)/2	S_{32}''

where: $S_{31}'' = \frac{1}{n-2}\sum_i Y_{i.}^2 - \frac{4}{n(n-2)} Y_{..}^2$;

$$S_{32}'' = \sum_{i<j} Y_{ij}^2 - \frac{1}{n-2}\sum_i Y_{i.}^2 + \frac{2}{(n-1)(n-2)} Y_{..}^2$$

The combined analysis of variance for data combined across two locations according to Gardner-Eberhart Analysis II and Analysis III (Gardner and Eberhart, 1966) was made using raw data from each individual location and analyzed by using DIALLEL-SAS05 program (Zhang et al., 2005).

3.5.3 Design II model analysis

The data of 10 × 10 interpopulation hybrids (10 lines from A crossed with 10 lines from B) obtained from C0 and C1 were analyzed for genetic effects according to Design II model (Comstock and Robinson, 1948; 1952). The statistical model and description for Design II are as follows:

$$Y_{ijk} = \mu + m_i + f_j + (m \times f)_{ij} + e_{ijk}$$

where: Y_{ijk} = the k^{th} observation on $i \times j^{th}$ progeny,

μ = the general mean,

m_i = the effect of the i^{th} male,

f_j = the effect of the j^{th} female,

$(m \times f)_{ij}$ = the interaction effect between the i^{th} male and the j^{th} female,

and e_{ijk} = the error effect associated with ijk^{th} observation.

The combined analysis of variance for data combined across two locations according to Design II model was conducted using raw data from each individual location. In the combined analysis, locations and entries were assumed random. Locations × (females × males) was used to test females × males, locations × females and locations × males, whereas pooled error was used to test locations × (females × males). Direct F-tests can be made for all sources of variation except for females and males. Satterthwaite's (1946) approximate test procedure was used to synthesize mean squares for F-tests of females and males (Hallauer and Miranda, 1988). For female, MS(F) + MS(L × FM) was tested with MS(L × F) + MS(L × M) with the following df:

$n_1 = (MS_F + MS_{(L \times FM)})^2/\{MS_F^2/(f-1) + MS_{(L \times FM)}^2/[(f-1)(m-1)(e-1)]\}$

$n_2 = (MS_{(L \times F)} + MS_{(L \times M)})^2/\{MS_{(L \times F)}^2/[(f-1)(e-1)] + MS_{(L \times M)}^2/[(m-1)(e-1)]\}$

For males, MS(M) + MS(L × FM) was tested with MS(L × F) + MS(L × M) with the following df:

$n_1 = (MS_M + MS_{(L \times FM)})^2/\{MS_M^2/(m-1) + MS_{(L \times FM)}^2/[(f-1)(m-1)(e-1)]\}$

$n_2 = (MS_{(L \times F)} + MS_{(L \times M)})^2/\{MS_{(L \times F)}^2/[(f-1)(e-1)] + MS_{(L \times M)}^2/[(m-1)(e-1)]\}$

Estimates of components of genetic variance were calculated as follows (Laosuwan, 2007):

$$\sigma_f^2 = \frac{MS(F) - MS(FM)}{l_B rL} = 1/2\,\sigma_A^2 \text{ ; F = 1}$$

$$\sigma_m^2 = \frac{MS(M) - MS(FM)}{l_A rL} = 1/2\,\sigma_A^2 \text{ ; F = 1}$$

$$\sigma_{fm}^2 = \frac{MS(FM) - MS(E)}{rL} = \sigma_D^2 \text{ ; F = 1}$$

$$\sigma_A^2 = \sigma_f^2 + \sigma_m^2$$

$$\sigma_D^2 = \sigma_{fm}^2$$

where: l_A and l_B are the number of lines derived from A and B populations, respectively; r is the number of replications; and L is the number of locations.

Estimation of gca effects from females (g_i) and males (g_j) and sca effects (s_{ij}) using entry mean were calculated as described below (Singh and Chaudhary, 1979; Laosuwan, 2007):

$$g_i = \frac{x_{i.}}{l_B rL} - \frac{x_{..}}{l_A l_B rL}$$

$$g_j = \frac{x_{.j}}{l_A rL} - \frac{x_{..}}{l_A l_B rL}$$

$$s_{ij} = \frac{x_{ij}}{rL} - \frac{x_{i.}}{l_B rL} - \frac{x_{.j}}{l_A rL} + \frac{x_{..}}{l_A l_B rL}$$

where: $x_{i.}$, $x_{.j}$, x_{ij} and $x_{..}$ are the totals of hybrids having the i^{th} female, j^{th} male, i^{th} female and j^{th} male as used as parents, and the grand total, respectively. The estimates of gca and sca effects were considered significant and highly significant if they were greater than two and three times, respectively, of their standard error of mean ($s_{\bar{x}}$; SE). The standard errors of mean for gca and sca effects were calculated according to Singh and Chaudhary (1979); SE for gca effects for females = $(MSE/rLl_B)^{1/2}$, SE for gca effects for males = $(MSE/rLl_A)^{1/2}$ and SE for sca effects = $(MSE/rL)^{1/2}$.

3.5.4 Tests of significance for two means

In this study, tests of differences between two means, where necessary, were made by using t-test (Snedecor and Cochran, 1967).

CHAPTER IV

RESULTS AND DISCUSSION

4.1 Population improvement

From the two cycles of MRRS, the results of each cycle of selection were divided into three parts, i.e., (1) S_1 testcross evaluation, (2) yield evaluation for populations per se, population crosses and population topcrosses and (3) evaluation of populations per se and population crosses according to Gardner-Eberhart Analysis II and Analysis III. The 10 traits collected were grain yield, days to 50% anthesis and silking, plant and ear heights, stalk and root lodging, foliar diseases, grain moisture and grain shelling. Data for other six traits, including seedling vigor, husk cover, plant and ear aspects, rotten ears and ears plant^{-1}, are shown in Appendix Tables 1B-20B. For rating score and percentage of corn borer infestation are shown in Appendix Tables 15B-20B.

Cycle 0

4.1.1 C0-S_1 testcross evaluation

Analyses of variance

Testcrosses were made by crossing AC0-S_1 and BC0-S_1 lines with the respective inbred testers, Ki 47 and Ki 46. The 250 S_1 testcrosses and six hybrids, including BIG 919, BIG 949, PIONEER 30A33, KSX 4156, Suwan 3853 and Suwan 3851, were evaluated at Suwan Farm in the 2001 late rainy season using a 16 × 16 simple lattice design to select the top 25 yielding testcrosses (10%) of each population for C1 population formation.

Mean squares from analyses of variance of 10 traits of the testcrosses of AC0-S_1 and BC0-S_1 are shown in Tables 4.1 and 4.2, respectively. Significant differences were observed among treatments of the AC0-S_1 testcross group for all traits except for stalk lodging (Table 4.1). Grain yield, days to 50% anthesis and silking, plant and ear heights, foliar diseases, grain moisture and grain shelling were highly significant (P < 0.01), while root lodging was significant (P < 0.05). For the group of BC0-S_1 testcrosses, all traits were significant (Table 4.2). The differences for grain moisture and grain shelling, however, exceeded only the 5% probability level.

Means of testcrosses

Means of 16 traits and grain type of the 25 top-yielders of AC0-S_1 and BC0-S_1 testcrosses are shown in Appendix Tables 3B and 4B, respectively. Mean grain yield of the 25 AC0-S_1 testcrosses was 8,703 kg ha^{-1} ranging from 8,323 to 10,296 kg ha^{-1} or 168.9% of the hybrid check, Suwan 3851 (Table 4.3). Mean grain yield of the 25 BC0-S_1 testcrosses was 8,859 kg ha^{-1} ranging from 8,498 to 9,461 kg ha^{-1} or 115.7% of the same check. The selected 25 S_1 testcrosses of each group gave significantly higher mean grain yield than both non-selected 225 S_1 testcrosses and six hybrid checks at P < 0.01. The results indicated that the inbred testers can discriminate among S_1 genotypes for combining ability for grain yield.

4.1.2 Yield evaluation for C0 and C1 populations per se, their population crosses and their population topcrosses

Combined analyses of variance

Twenty-five C0-S_2 lines, each corresponded to the 25 top-yielders of C0-S_1 testcrosses, were recombined to produce AC1 and BC1 populations. The four populations

Table 4.1 Mean squares from analyses of variance of 10 traits of the testcrosses of AC0-S_1 at Suwan Farm in the 2001 late rainy season.

			Days to 50%		Height		Lodging		Foliar	Grain	Grain
Source of variation	**df**	**Grain yield**	**Ant.**[(1)]	**Silk.**[(2)]	**Plant**	**Ear**	**Stalk**	**Root**	**dis.**[(3)]	**moist.**[(4)]	**shell.**[(5)]
		kg ha^{-1}	d		cm		%	(1-5)		%	
Replications (Rep.)	1	12935640.00	16.89	23.63	1492.63	1210.94	5250.34	3.78	0.95	506.06	1.10
Blocks/rep. (adj.)	30	798259.00	4.12	4.43	422.28	260.42	314.84	0.40	0.10	5.67	2.23
Treatments (unadj.)	255	1231212.00 **	3.70 **	4.65 **	172.14	117.83	222.85	0.30	0.21 **	6.27 **	3.57 **
Treatments (adj.)	255	-	-	-	129.60 **	95.09 **	-	0.27 *	-	-	-
Intra-block error	225	608444.00	2.17	2.90	77.32	45.50	163.53	0.19	0.08	3.60	2.03
CV (%)		10.74	2.99	3.39	4.07	5.51	103.48	20.53	10.80	7.75	1.79

*, ** Significant at the 0.05 and 0.01 probability levels, respectively.

[(1), (2)] Days to 50% anthesis and silking, [(3)] foliar diseases, [(4)] grain moisture and [(5)] grain shelling.

Table 4.2 Mean squares from analyses of variance of 10 traits of the testcrosses of BC0-S_1 at Suwan Farm in the 2001 late rainy season.

			Days to 50%		Height		Lodging		Foliar	Grain	Grain
Source of variation	**df**	**Grain yield**	**Ant.**	**Silk.**	**Plant**	**Ear**	**Stalk**	**Root**	**dis.**	**moist.**	**shell.**
		kg ha^{-1}	d		cm		%	(1-5)		%	
Replications (Rep.)	1	4252755.00	9.57	28.13	22.53	1088.11	442.63	0.41	0.00	677.47	21.23
Blocks/rep. (adj.)	30	1802007.00	4.63	8.00	292.12	166.95	158.27	0.37	0.28	9.51	11.36
Treatments (unadj.)	255	1118994.00	2.24	3.33	119.43	82.05	133.72	0.31	0.16	4.59	11.91 *
Treatments (adj.)	255	1031052.78 **	1.63 **	2.56 **	92.37 **	62.07 **	121.26 **	0.27 **	0.13 **	4.20 *	-
Intra-block error	225	601327.00	0.83	1.53	48.55	30.82	67.78	0.15	0.08	3.03	8.43
CV (%)		10.62	1.82	2.48	3.55	5.03	110.09	18.54	12.13	7.03	3.80

*, ** Significant at the 0.05 and 0.01 probability levels, respectively.

Table 4.3 Grain yield of C0-S_1 testcrosses compared with Suwan 3851 (hybrid check) at Suwan Farm in the 2001 late rainy season.

Entry	Number	Grain yield Range	Grain yield Mean	Relative to check
		kg ha^{-1}		%
Testcrosses of AC0-S_1 x Ki 47				
Total S_1 testcrosses	250	5,204-10,296	7,427	144.1
Top 10 testcrosses	10	8,684-10,296	9,070	176.0
Top 25 testcrosses	25	8,323-10,296	8,703	168.9
Hybrid checks	6	4,503-7,570	6,196	120.2
Suwan 3851 (Check)	1	5,154	5,154	100.0
Testcrosses of BC0-S_1 x Ki 46				
Total S_1 testcrosses	250	5,351-9,461	7,595	99.2
Top 10 testcrosses	10	8,916-9,461	9,129	119.2
Top 25 testcrosses	25	8,498-9,461	8,859	115.7
Hybrid checks	6	5,557-7,897	7,092	92.6
Suwan 3851 (Check)	1	7,655	7,655	100.0

(AC0, AC1, BC0 and BC1) were crossed among them in a diallel cross and crossed with respective inbred testers, Ki 47 and Ki 46, to produce six population crosses and four population topcrosses, respectively. Sixteen populations, including four populations per se, six population crosses, four population topcrosses and two population checks (Suwan3(S)C4 and Suwan5(S)C3), were evaluated at two locations in the 2002 late rainy season using a randomized complete block design with four replications to determine progress from selection from both within and between groups of the populations.

Mean squares from combined analyses of variance of 10 traits of the 14 populations and two population checks are shown in Table 4.4. Highly significant differences were detected among locations for all traits except for stalk lodging (P < 0.05). The C0 vs. C1 populations per se were significantly different for grain yield (P < 0.05), days to 50% silking (P < 0.01) and foliar diseases (P < 0.05). Population crosses were highly significant for grain yield and foliar diseases, while days to 50% silking and ear height were significant. However, no significant differences were detected for all traits evaluated for the C0 vs. C1 population topcrosses. Grain yield were highly significant in the comparison between all populations vs. checks, and significant for the populations per se vs. population crosses and population topcrosses. The results showed obvious responses to selection for grain yield of the populations per se and population crosses. Interaction of treatments with locations showed a highly significant difference for plant height, and significant differences for days to 50% anthesis and silking.

Means of populations

Means of 16 traits including grain yield and grain type of the 14 populations and two population checks are shown in Appendix Table 6B. Table 4.5 shows higher means for grain yield of C1 populations including AC1, BC1, AC1 × BC1, AC1 × Ki 47 and BC1 × Ki 46 than C0 populations including AC0, BC0, AC0 × BC0, AC0 × Ki 47 and BC0 × Ki 46, for 5.3, 6.9, 10.3, 6.9 and 7.0%, respectively. Importantly, the population cross of AC1 × BC1 gave significantly higher yield than AC0 × BC0 at $P < 0.05$, and all populations, especially C1 populations, gave higher yield than the check, Suwan5(S)C3. The results indicated the progress from selection for grain yield for all C1 populations including populations per se, population crosses and population topcrosses.

Mean grain yield of populations per se was not significantly different from those of population crosses and the checks (Suwan3(S)C4 and Suwan5(S)C3), while population topcrosses and population crosses gave significantly higher mean grain yield than the checks at $P < 0.01$ and $P < 0.05$, respectively. Population topcrosses also gave

Table 4.4 Mean squares from analyses of variance of 10 traits of 14 populations and two population checks from data combined over two locations in the 2002 late rainy season.

Source of variation	df	Grain yield	Days to 50% Ant.	Days to 50% Silk.	Height Plant	Height Ear	Lodging Stalk	Lodging Root	Foliar dis.	Grain moist.	Grain shell.
		kg ha^{-1}	d		cm		%	(1-5)		%	
Locations (L)	1	321449272.02 **	492.20 **	381.57 **	47212.80 **	4773.87 **	44.19 *	2.26 **	15.13 **	28.19 **	916.33 **
Replications within location (R/L)	6	3134103.31	5.06	7.29	178.07	262.49	11.56	0.42	0.26	2.34	19.53
Treatments (T)	15	3224083.51 **	3.14	4.26 *	181.31	210.30 **	7.56	0.26	0.11 *	4.36	5.02 *
Populations per se	3	257246.07	3.61	5.50 **	320.25	76.17	12.54	0.24	0.19 *	7.26	2.45
C0 populations per se	1	63577.62	1.56	6.25 **	275.56	156.25	35.60	0.56	0.14 *	10.69	0.21
C1 populations per se	1	10998.62	2.25	2.25 *	35.40	13.14	0.41	0.14	0.14 *	5.45	0.65
C0 vs. C1 populations per se	1	697161.96 *	7.03	8.00 **	649.80	59.13	1.59	0.01	0.28 *	5.64	6.50
Population crosses	5	1407122.87 **	2.98	2.73 *	109.91	112.14 *	3.44	0.16	0.10 **	2.33	3.04
Population topcrosses	3	1368347.64	1.36	2.75	229.90	389.74 *	6.31	0.13	0.09	2.25	9.84
C0 population topcrosses	1	1296793.14	1.56	5.06	435.77	689.06 *	1.42	0.14	0.14	1.05	11.51
C1 population topcrosses	1	1461074.64	1.00	3.06	241.80	365.77 *	8.77	0.25	0.02	1.43	14.03
C0 vs. C1 population topcrosses	1	1347175.14	1.53	0.13	12.13	114.38	8.74	0.01	0.13	4.28	3.98
Checks	1	932836.37	0.06	0.06	150.06 *	9.00	1.56	0.00	0.25	0.85	9.55
All populations vs. Checks	1	14741301.93 **	0.70	1.70	131.08	1118.98	10.82 *	0.07	0.04	7.72	2.73
per se vs. Crosses and topcrosses	1	10045832.37 *	8.75 *	7.56	2.09	46.46	0.03	1.00	0.00	9.21	4.36
Population crosses vs. Topcrosses	1	10728886.53	7.75	16.13 *	236.46 *	21.63	27.21	0.96	0.02	7.41	6.59
T x L	15	164566.62	1.36 *	1.49 *	132.45 **	30.28	6.62	0.23	0.04	2.56	2.02
Populations per se x L	3	35744.82	1.20	0.17	112.05	16.15	7.48	0.17	0.01	3.14	3.83
Population crosses x L	5	73188.17	0.68	0.40	176.27 *	15.20	8.19	0.16	0.01	2.18	0.90
Population topcrosses x L	3	387554.47	2.36 *	3.71 **	229.10 **	35.15	7.76	0.03	0.05	2.36	1.97
Checks x L	1	309882.35	3.06 *	3.06 *	0.56	81.00	5.81	1.00 **	0.06	1.93	0.18
(All populations vs. Checks) x L	1	3525.55	2.90 *	5.31 **	25.01	133.84	0.02	0.59 *	0.02	8.58 *	2.07
(per se vs. Crosses and topcrosses) x L	1	3724.29	0.01	0.23	55.98	4.77	2.00	0.19	0.20 *	0.10	2.77
(Population crosses vs. Topcrosses) x L	1	515528.41	0.35	0.08	0.40	4.58	4.72	0.23	0.05	0.38	3.34
Pooled error	90	237603.14	0.70	0.73	56.73	49.93	5.73	0.13	0.05	1.48	1.54
CV (%)		9.12	1.49	1.50	3.49	6.61	122.51	19.35	6.51	5.00	1.58

*, ** Significant at the 0.05 and 0.01 probability levels, respectively.

significantly higher mean grain yield than populations per se at $P < 0.01$. The higher yield of population topcrosses than population crosses should be due to high general and specific combining ability of the inbred testers, Ki 46 and Ki 47, with the component lines (Aekatasanawan et al., 1998; 2001a; 2001b; 2005). The results agreed with the suggestions of Hull (1945), Horner et al. (1963) and Horner et al. (1989) that the inbred testers should have high general combining ability. The results signified that testcross hybrids should have higher potential for yield than interpopulation hybrids developed in the part of hybrid development.

Table 4.5 Mean grain yield of C0 and C1 populations compared with Suwan5(S)C3 (population check) from data combined over two locations in the 2002 late rainy season.

Entry	**Grain yield**	**Relative to C0**	**Relative to check**
	kg ha^{-1}	%	
AC0	4,918	100.0	104.8
AC1	5,176	105.3	110.3
BC0	4,792	100.0	102.1
BC1	5,124	106.9	109.2
AC0 x BC0	5,313	100.0	113.3
AC1 x BC1	5,860	110.3	124.9
AC0 x Ki 47	6,193	100.0	132.0
AC1 x Ki 47	6,621	106.9	141.1
BC0 x Ki 46	5,624	100.0	119.9
BC1 x Ki 46	6,017	107.0	128.3
Suwan5(S)C3 (Check)	4,691	-	100.0
LSD 0.05	484.20	-	-
LSD 0.01	641.37	-	-

4.1.3 Evaluation of C0 and C1 populations per se and their population crosses according to Gardner-Eberhart Analysis II and Analysis III

Combined analyses of variance

Data for C0 and C1 populations per se and their diallel crosses were analyzed using Gardner-Eberhart Analysis II and Analysis III to obtain the estimates of genetic effects including variety effects (v_i), variety heterosis effects (h_i), average heterosis ($\bar{h}$) and gca and sca effects.

Mean squares from combined analyses of variance using Gardner-Eberhart Analysis II and Analysis III for 10 traits of four populations per se and their six diallel crosses are shown in Table 4.6. For Analysis II, varieties were highly significant for days to 50% silking, and significant for grain yield, days to 50% anthesis and ear height. The partitioning of heterosis showed that variety heterosis was significant for grain yield and foliar diseases, while specific heterosis was significant only for foliar diseases. Mean squares for gca was highly significant for grain yield and days to 50% anthesis, and significant for days to 50% silking. No significant interactions were detected for grain yield of varieties with locations, heterosis with locations and gca with locations. Mean squares for sca was higher than that of gca for grain yield, days to 50% silking, plant and ear heights, stalk lodging and foliar diseases. Both analyses indicated that variation for grain yield among diallel entries was due to additive and nonadditive genetic effects.

Estimates of variety effects

Estimates of variety effects (v_i) of 10 traits analyzed according to Gardner-Eberhart Analysis II are shown in Table 4.7. AC1 and BC1 populations gave positive variety effects for grain yield, while AC0 and BC0 populations gave negative variety

Table 4.6 Mean squares from Gardner-Eberhart Analysis II and Analysis III of 10 traits from four populations per se and their six diallel crosses, from data combined over two locations in the 2002 late rainy season.

			Days to 50%		Height		Lodging		Foliar	Grain	Grain
Source of variation	**df**	**Grain yield**	**Ant.**	**Silk.**	**Plant**	**Ear**	**Stalk**	**Root**	**dis.**	**moist.**	**shell.**
		kg ha^{-1}	d		cm		%		(1-5)	%	
Gardner-Eberhart Analysis II											
Varieties	3	697146.45 *	6.74 *	7.06 **	422.14	142.92 *	3.84	0.43	0.16	8.83	4.95
Heterosis	6	1058856.96 **	0.96	1.28	47.91	58.82	7.78	0.06	0.10	1.59	1.14
Average heterosis	1	2543101.05	2.55	0.83	55.90	19.24	3.67	0.28	0.00	2.86	0.79
Variety heterosis	3	192197.62 *	0.29	0.61	4.94	10.07	12.07	0.01	0.06 *	1.39	2.53
Specific heterosis	2	2569660.16	2.33	3.58	114.55	165.13	3.54	0.10	0.20 *	1.39	0.07
Varieties x L	3	33403.47	0.69	0.06	197.86 *	5.65	6.59	0.13	0.02	5.52 *	4.42 *
Heterosis x L	6	68277.44	0.81	0.38	90.65	17.66	5.60	0.16	0.03	0.67	0.53
Average heterosis x L	1	117740.51	0.10	0.30	50.57	1.31	4.68	0.04	0.25 *	0.29	0.63
Variety heterosis x L	3	7637.36	0.59	0.28	41.33	22.36	5.25	0.30	0.00	0.98	0.65
Specific heterosis x L	2	175026.40	1.58	0.75	249.97 **	20.22	13.93	0.02	0.01	0.41	0.40
Gardner-Eberhart Analysis III											
Varieties	3	257246.07	3.61	5.50 **	320.26	76.17	12.54	0.24	0.19 *	7.26	2.45
Varieties vs. Crosses	1	2543101.05	2.55	0.83	55.90	19.24	3.67	0.28	0.00	2.86	0.79
Crosses	5	1407122.86 **	2.98	2.73 *	109.91	112.14 *	3.44	0.16	0.10 **	2.33	3.04
GCA	3	632098.00 **	3.42 **	2.17 *	106.82	76.82	3.38	0.20	0.03	2.96	5.03
SCA	2	2569660.16	2.33	3.58	114.55	165.13	3.54	0.10	0.20 *	1.39	0.07
Varieties x L	3	35744.82	1.20	0.17	112.06	16.15	7.48	0.17	0.01	3.14	3.83 *
(Varieties vs. Crosses) x L	1	117740.51	0.10	0.30	50.57	1.31	4.68	0.04	0.25 *	0.29	0.63
Crosses x L	5	73188.17	0.68	0.40	176.27 **	15.20	8.19	0.16	0.01	2.18	0.90
GCA x L	3	5296.01	0.08	0.17	127.13	11.86	4.37	0.26	0.01	3.36	1.23
SCA x L	2	175026.40	1.58	0.75	249.97 **	20.22	13.93	0.02	0.01	0.41	0.40
SCA : GCA		4.07	0.68	1.65	1.07	2.15	1.05	0.50	6.50	0.47	0.01

*, ** Significant at the 0.05 and 0.01 probability levels, respectively.

effects. The results indicated that grain yield of AC1 and BC1 were higher than the average yield of all parental populations, and indicated the improvement for grain yield of populations per se. AC1 also gave positive variety effects for grain shelling, while BC1 also gave negative variety effects for stalk lodging and foliar diseases and gave positive variety effects for grain shelling. Likewise, AC1 also showed the improvement for grain shelling percentage, and BC1 also showed the improvement for stalk lodging percentage, foliar diseases score and grain shelling percentage.

Table 4.7 Estimates of variety effects (v_i) from Gardner-Eberhart Analysis II of 10 traits from four populations per se and their six diallel crosses, from data combined over two locations in the 2002 late rainy season.

	v_i									
Populations	**Grain**	**Days to 50%**		**Height**		**Lodging**		**Foliar**	**Grain**	**Grain**
	yield	**Ant.**	**Silk.**	**Plant**	**Ear**	**Stalk**	**Root**	**dis.**	**moist.**	**shell.**
	kg ha^{-1}	d		cm		%		(1-5)	%	
AC0	-84.57	-0.16	0.13	-0.36	1.77	-1.27	0.17	0.00	0.40	-0.57
AC1	173.82	0.84	0.88	5.99	2.27	-0.06	0.11	0.00	1.00 *	0.25
BC0	-210.64	-0.78	-1.13	-8.66	-4.48	1.71 *	-0.20	0.19	-1.24 **	-0.34
BC1	121.38	0.09	0.13	3.02	0.45	-0.38	-0.08	-0.19	-0.16	0.65
SE†	565.76	0.71	0.66	6.78	3.02	0.83	0.13	0.13	0.44	0.95

† Standard error.

*, ** Significant at the 0.05 and 0.01 probability levels, respectively.

Estimates of variety heterosis effects and average heterosis

Table 4.8 shows estimates of variety heterosis effects (h_i) and average heterosis ($\bar{h}$) from Gardner-Eberhart Analysis II for 10 traits. For grain yield, BC1 gave positive variety heterosis effects which was higher than that of BC0, whereas AC1 gave negative variety heterosis effects which was lower than that of AC0. The results indicated that AC1 and BC1 manifested negative and positive heterosis effects for grain yield. The average heterosis is the difference between the mean of all crosses and the mean of all parents, the positive and high estimate for grain yield indicated higher mean grain yield of all crosses than the mean of all parental populations.

Table 4.8 Estimates of variety heterosis effects (h_i) and average heterosis ($\bar{h}$) from Gardner-Eberhart Analysis II of 10 traits from four populations per se and their six diallel crosses, from data combined over two locations in the 2002 late rainy season.

Populations	h_i									
	Grain yield	Days to 50%		Height		Lodging		Foliar dis.	Grain moist.	Grain shell.
		Ant.	Silk.	Plant	Ear	Stalk	Root			
	kg ha^{-1}	d		cm		%		(1-5)	%	
AC0	10.89	0.14	0.19	0.52	-0.89	1.26	0.01	0.06	-0.04	0.00
AC1	-53.89	0.14	-0.06	-0.70	1.18	-0.09	0.04	-0.03	0.00	-0.68
BC0	-136.78	-0.17	0.19	0.65	-0.70	-1.33	-0.02	-0.09	0.46	0.28
BC1	179.79	-0.11	-0.31	-0.46	0.40	0.16	-0.02	0.06	-0.42	0.41
$\bar{h}$	363.94	-0.36	-0.21	1.71	1.00	0.44	-0.12	0.00	0.39	0.20
SE† for h_i	489.97	0.62	0.57	5.87	2.62	0.72	0.11	0.12	0.38	0.82
SE for $\bar{h}$	421.70	0.53	0.49	5.05	2.25	0.62	0.10	0.10	0.33	0.70

† Standard error.

Estimates of gca and sca effects

Estimates of gca and sca effects from Gardner-Eberhart Analysis III of 10 traits are shown in Table 4.9. For grain yield, AC1 and BC1 gave positive gca effects, while AC0 and BC0 gave negative gca effects. The results indicated higher frequency of favorable alleles for grain yield in AC1 and BC1 and the improvement of gca effects for grain yield of the populations per se. The improvement for gca effects in AC1 were also found for stalk lodging percentage and foliar diseases score, and in BC1 for foliar diseases score, grain moisture and grain shelling percentage. Estimates of sca effects for grain yield showed that four population crosses of A × B gave positive sca effects, signifying the potential of interpopulation hybrids.

Table 4.9 Estimates of gca and sca effects from Gardner-Eberhart Analysis III of 10 traits of four populations per se and their six diallel crosses, from data combined over two locations in the 2002 late rainy season.

Traits	Populations	AC0	AC1	BC0	BC1	GCA effects
		SCA effects				
Grain yield	AC0		-462.58	220.54	242.05	-31.40
(kg ha^{-1})	AC1			242.05	220.54	33.02
	BC0				-462.58	-242.10
	BC1					240.48
	SE† (gca effects)	400.06				
	SE (sca effects)	377.18				
Days to 50% anthesis	AC0		0.33	-0.42	0.08	0.06
(d)	AC1			0.08	-0.42	0.56
	BC0				0.33	-0.56
	BC1					-0.06
	SE (gca effects)	0.50				
	SE (sca effects)	0.48				
Days to 50% silking	AC0		0.33	-0.54	0.21	0.25
(d)	AC1			0.21	-0.54	0.38
	BC0				0.33	-0.38
	BC1					-0.25
	SE (gca effects)	0.47				
	SE (sca effects)	0.44				
Plant height	AC0		-3.04	1.98	1.06	0.34
(cm)	AC1			1.06	1.98	2.29
	BC0				-3.04	-3.68
	BC1					1.05
	SE (gca effects)	4.80				
	SE (sca effects)	4.52				
Ear height	AC0		-3.22	0.02	3.20	0.00
(cm)	AC1			3.20	0.02	2.32
	BC0				-3.22	-2.94
	BC1					0.63
	SE (gca effects)	2.14				
	SE (sca effects)	2.01				
Stalk lodging	AC0		-0.32	0.54	-0.23	0.63
(%)	AC1			-0.23	0.54	-0.12
	BC0				-0.32	-0.47
	BC1					-0.03
	SE (gca effects)	0.59				
	SE (sca effects)	0.56				

Table 4.9 (continued)

Traits	Populations	AC0	AC1	BC0	BC1	GCA effects
		SCA effects				
Root lodging	AC0		-0.08	0.01	0.07	0.09
(1-5)	AC1			0.07	0.01	0.09
	BC0				-0.08	-0.13
	BC1					-0.06
	SE (gca effects)	0.09				
	SE (sca effects)	0.09				
Foliar diseases	AC0		-0.03	0.13	-0.09	0.06
(1-5)	AC1			-0.09	0.13	-0.03
	BC0				-0.03	0.00
	BC1					-0.03
	SE (gca effects)	0.09				
	SE (sca effects)	0.09				
Grain moisture	AC0		-0.11	0.33	-0.22	0.16
(%)	AC1			-0.22	0.33	0.50
	BC0				-0.11	-0.16
	BC1					-0.50
	SE (gca effects)	0.31				
	SE (sca effects)	0.29				
Grain shelling	AC0		-0.01	-0.06	0.07	-0.28
(%)	AC1			0.07	-0.06	-0.56
	BC0				-0.01	0.11
	BC1					0.73
	SE (gca effects)	0.67				
	SE (sca effects)	0.63				

† Standard error.

Cycle 1

4.1.4 C1-S_1 testcross evaluation

Analyses of variance

Testcrosses were made by crossing AC1-S_1 and BC1-S_1 lines with the respective inbred testers, Ki 47 and Ki 46. The 250 S_1 testcrosses and six hybrids, including KSX 4501, KSX 4505, KSX 4507, BIG 949, KSX 4452 (Suwan 4452) and Suwan 3851, were evaluated at Suwan Farm in the 2003 early rainy season using a

16×16 simple lattice design to select the top 25 yielding testcrosses (10%) of each population for C2 population formation.

Mean squares from analyses of variance of 10 traits of the testcrosses of AC1-S_1 and BC1-S_1 are shown in Tables 4.10 and 4.11, respectively. From the group of AC1-S_1 testcrosses, all traits were highly significant. The group of BC1-S_1 testcrosses also showed the same results, but days to 50% anthesis and silking were not significant.

Means of testcrosses

Means of 15 traits and grain type of the 25 top-yielders of AC1-S_1 and BC1-S_1 testcrosses are shown in Appendix Tables 13B and 14B, respectively. Mean grain yield of the 25 AC1-S_1 testcrosses was 8,865 kg ha^{-1} ranging from 8,588 to 9,415 kg ha^{-1} or 195.5% of the hybrid check, Suwan 3851 (Table 4.12). Mean grain yield of the 25 BC1-S_1 testcrosses was 9,087 kg ha^{-1} ranging from 8,787 to 9,975 kg ha^{-1} or 130.7% of the same check. Mean grain yield of the selected 25 AC1-S_1 testcrosses was significantly higher than those of non-selected 225 S_1 testcrosses and six hybrid checks at $P < 0.01$, while that of the 25 BC1-S_1 testcrosses was significantly higher than those of non-selected 225 S_1 testcrosses and six hybrid checks at $P < 0.01$ and $P < 0.05$, respectively.

The comparison between mean grain yield of the 25 AC0-S_1 testcrosses and the 25 AC1-S_1 testcrosses showed that the AC1 testcrosses gave higher yield than the AC0 testcrosses for 26.6% relative to the same check, Suwan 3851 (195.5% of the check in Table 4.12 vs. 168.9% of the check in Table 4.3). Similarly, the 25 BC1-S_1 testcrosses gave higher mean grain yield than the 25 BC0-S_1 testcrosses for 15.0% relative to the same check (130.7% of the check in Table 4.12 vs. 115.7% of the check in Table 4.3). The results indicated mean improvement for grain yield of C1 populations.

Table 4.10 Mean squares from analyses of variance of 10 traits of the testcrosses of AC1-S_1 at Suwan Farm in the 2003 early rainy season.

			Days to 50%		Height		Lodging		Foliar	Grain	Grain
Source of variation	**df**	**Grain yield**	**Ant.**	**Silk.**	**Plant**	**Ear**	**Stalk**	**Root**	**dis.**	**moist.**	**shell.**
		kg ha^{-1}	.... d		.... cm		%	.... (1-5)		.... %	
Replications (Rep.)	1	11634967.00	7.03	6.57	141.33	1.42	182.27	0.56	2.32	7.71	0.76
Blocks/rep. (adj.)	30	892598.00	2.38	1.07	71.86	49.31	99.45	0.84	0.25	3.50	8.72
Treatments (unadj.)	255	1062758.00 **	0.93	0.80	80.42 **	64.01 **	99.35 **	0.39	0.32	3.09	16.73 **
Treatments (adj.)	255	-	0.68 **	0.70 **	-	-	-	0.29 **	0.28 **	2.91 **	-
Intra-block error	225	674030.00	0.42	0.38	53.47	41.00	62.59	0.19	0.10	1.21	9.75
CV (%)		10.97	1.20	1.13	2.98	4.40	68.41	31.61	12.62	4.52	3.75

** Significant at the 0.01 probability level.

Table 4.11 Mean squares from analyses of variance of 10 traits of the testcrosses of BC1-S_1 at Suwan Farm in the 2003 early rainy season.

			Days to 50%		Height		Lodging		Foliar	Grain	Grain
Source of variation	**df**	**Grain yield**	**Ant.**	**Silk.**	**Plant**	**Ear**	**Stalk**	**Root**	**dis.**	**moist.**	**shell.**
		kg ha^{-1}	.... d		.... cm		%	.... (1-5)		.... %	
Replications (Rep.)	1	52288181.00	1.64	0.01	300.13	1332.57	951.72	3.36	0.06	6.92	64.80
Blocks/rep. (adj.)	30	1438220.00	1.10	1.12	192.11	96.22	95.42	0.71	1.38	1.95	13.91
Treatments (unadj.)	255	1343320.00	0.64	0.66	128.04	123.84	109.23 **	0.48	0.39	2.50	14.60 **
Treatments (adj.)	255	1303736.28 **	0.54	0.59	104.40 **	113.24 **	-	0.44 **	0.22 **	2.26 **	-
Intra-block error	225	732221.00	0.51	0.53	62.31	36.43	64.19	0.23	0.14	0.92	7.55
CV (%)		11.45	1.31	1.34	3.44	4.53	84.09	30.32	15.21	4.36	3.57

** Significant at the 0.01 probability level.

Table 4.12 Grain yield of C1-S_1 testcrosses compared with Suwan 3851 (hybrid check) at Suwan Farm in the 2003 early rainy season.

Entry	Number	Grain yield Range	Grain yield Mean	Relative to check
		kg ha^{-1}		%
Testcrosses of AC1-S_1 x Ki 47				
Total S_1 testcrosses	250	5,899-9,415	7,652	168.7
Top 10 testcrosses	10	8,886-9,415	9,077	200.2
Top 25 testcrosses	25	8,588-9,415	8,865	195.5
Hybrid checks	6	4,535-7,700	6,507	143.5
KSX 4452 (Suwan 4452)	1	6,679	6,679	147.3
Suwan 3851 (Check)	1	4,535	4,535	100.0
Testcrosses of BC1-S_1 x Ki 46				
Total S_1 testcrosses	250	5,776-9,975	7,706	110.8
Top 10 testcrosses	10	9,131-9,975	9,346	134.4
Top 25 testcrosses	25	8,787-9,975	9,087	130.7
Hybrid checks	6	4,940-8,838	6,969	100.2
KSX 4452 (Suwan 4452)	1	8,838	8,838	127.1
Suwan 3851 (Check)	1	6,952	6,952	100.0

4.1.5 Yield evaluation for C0, C1 and C2 populations per se, their population crosses and their population topcrosses

Combined analyses of variance

Twenty-five C1-S_2 lines, each corresponded to the 25 top-yielders of C1-S_1 testcrosses, were recombined to produce AC2 and BC2 populations. The six populations (AC0, AC1, AC2, BC0, BC1 and BC2) were crossed among them in a diallel cross and crossed with respective inbred testers, Ki 47 and Ki 46, to produce 15 population crosses and six population topcrosses, respectively. Thirty populations, including six populations per se, 15 population crosses, six population topcrosses and three population checks (Suwan3(S)C4, Suwan1(S)C12 and Suwan5(S)C4), were evaluated at two locations using a 5 × 6 triple rectangular lattice design to determine progress from selection from both within and between groups of the populations.

Mean squares from combined analyses of variance of 10 traits of the 27 populations and three checks are shown in Table 4.13. Highly significant differences were detected among locations for grain yield, days to 50% anthesis and silking, plant and ear heights, stalk and root lodging and grain moisture, and a significant difference was detected for foliar diseases. The significant difference for grain yield was found in the comparison between population crosses vs. population topcrosses at $P < 0.05$. The C0 vs. C1 and C2 populations per se was significant for foliar diseases. However, no significant differences were observed for all traits evaluated for the C1 vs. C2 populations per se. Population crosses were highly significant for ear height and grain moisture, and significant for plant height. The C0 vs. C1 and C2 population topcrosses was significant only for plant height, and no significant differences were detected for all traits evaluated for the C1 vs. C2 population topcrosses. Only plant height was significant ($P < 0.01$) for the comparisons between all populations vs. checks. Interaction of treatments with locations was not significant for all traits.

Means of populations

Means of 18 traits and grain type of the 27 populations and three population checks are shown in Appendix Table 16B. AC1 and AC2 populations gave higher grain yield than AC0 population for 6.9% and 11.6%, respectively (Table 4.14). In contrast, BC1 and BC2 populations had grain yield 94.7% and 99.0% of the BC0, respectively, but they were not significantly different from BC0. Population A tended to be improved for grain yield, but the improvement was not found for population B. Grain yield of population crosses of AC1 × BC1 and AC2 × BC2 were 100.9% and

Table 4.13 Mean squares from analyses of variance of 10 traits of 27 populations and three population checks from data combined over two locations in the 2005 early rainy season.

Source of variation	df	Grain yield	Days to 50% Ant.	Days to 50% Silk.	Height Plant	Height Ear	Lodging Stalk	Lodging Root	Foliar dis.	Grain moist.	Grain shell.
		kg ha^{-1}	d		cm		%	(1-5)		%	
Locations (L)	1	18270053.87 **	410.82 **	315.87 **	11731.74 **	8393.62 **	796.33 **	21.40 **	0.19 *	150.98 **	3.42
Treatments (T)	29	648187.39 **	0.54	0.87	98.18 **	52.92 **	11.71	0.06	0.03	0.45	1.44
Populations per se	5	128992.98	0.28	0.49	64.24	12.08	22.92	0.10	0.06 *	0.55	0.50
C0 populations per se	1	367702.77	0.22	0.12	134.91	14.63	81.83	0.17	0.08 *	0.01	0.57
C1 populations per se	1	23002.27	0.23	0.22	10.43	1.53	9.53	0.02	0.02	0.86	1.57
C2 populations per se	1	21957.31	0.14	0.15	0.02	4.56	7.91	0.16	0.00	0.67	0.01
C0 vs. C1 and C2 populations per se	1	77453.62	0.54	1.73	78.12	1.13	10.20	0.03	0.14 *	0.08	0.01
C1 vs. C2 populations per se	1	154848.91	0.28	0.23	97.72	38.54	5.12	0.12	0.05	1.12	0.34
Population crosses	14	260630.80	0.43	0.44	70.03 *	33.35 **	8.69	0.03	0.02	0.43 **	1.00
Population topcrosses	5	331347.82	0.29	0.24	160.06 *	78.21	2.11	0.11	0.03	0.34	3.20
C0 population topcrosses	1	95784.06	0.04	0.05	345.22 *	142.68 *	3.84	0.06	0.03	0.00	4.45
C1 population topcrosses	1	4944.20	0.13	0.26	172.40 *	115.46 *	1.31	0.00	0.12	0.45	8.28 *
C2 population topcrosses	1	970885.06	0.29	0.06	93.70	53.58	3.54	0.43	0.00	0.06	3.07
C0 vs. C1 and C2 population topcrosses	1	387141.72	0.82	0.81	187.27 *	79.10	0.28	0.00	0.01	1.18	0.09
C1 vs. C2 population topcrosses	1	197984.07	0.19	0.00	1.73	0.26	1.57	0.03	0.01	0.02	0.09
Checks	2	143659.73	0.31	0.69	6.56	14.68	5.44	0.04	0.00	0.13	1.22
All populations vs. Checks	1	1368261.34	0.02	0.24	474.05 **	425.07	47.11	0.10	0.06	1.97	0.71
per se vs. Crosses and topcrosses	1	4757045.68	0.98	0.80	63.18	155.18	0.01	0.01	0.01	0.01	4.93
Population crosses vs. Topcrosses	1	6434272.57 *	5.32	12.93	194.89	6.85	34.72	0.04	0.03	0.34	1.17
T x L	29	126167.41	0.48	0.82	23.66	10.82	9.67	0.09	0.03	0.30	1.21
Populations per se x L	5	95721.46	0.28	0.46	30.82	15.68	15.53	0.12	0.01	0.31	1.25
Population crosses x L	14	109704.55	0.26	0.34	23.41	7.88	8.44	0.06	0.03	0.11	0.98
Population topcrosses x L	5	202597.86	0.24	0.24	23.56	15.61	3.82	0.09	0.08	0.82	0.80
Checks x L	2	154948.23	0.16	0.22	8.23	6.51	6.32	0.13	0.00	0.04	0.92
(All populations vs. Checks) x L	1	61921.79	0.05	0.19	0.04	10.18	30.82	0.10	0.09	0.38	2.27
(per se vs. Crosses and topcrosses) x L	1	248863.39	2.47 *	2.79 *	66.46	23.20	0.42	0.05	0.02	0.86	3.89
(Population crosses vs. Topcrosses) x L	1	10713.07	4.88 **	12.01 **	3.60	0.67	21.68	0.31	0.02	0.07	3.02
Pooled error	86	214014.72	0.51	0.53	55.87	35.78	26.22	0.15	0.05	0.48	2.34
CV (%)		5.18	1.36	1.74	2.04	2.41	67.89	12.32	6.65	2.83	1.33

*, ** Significant at the 0.05 and 0.01 probability levels, respectively.

102.4%, respectively, of AC0 × BC0. The population topcross of AC1 × Ki 47 gave significantly higher grain yield than AC0 × Ki 47 for 10.0% at $P < 0.05$, but AC2 × Ki 47 gave lower grain yield than AC0 × Ki 47 and AC1 × Ki 47. However, BC1 × Ki 46 and BC2 × Ki 46 gave higher grain yield than BC0 × Ki 46. The results for population crosses and population topcrosses indicated certain degrees of grain yield improvement for both groups of the populations except AC2 × Ki 47. In addition, AC2, BC0, population crosses of C0, C1 and C2 and all population topcrosses had higher grain yield than the check, Suwan5(S)C4.

Means for grain yield of population crosses and topcrosses were significantly higher than that of populations per se at $P < 0.01$. The results indicated the expression of heterosis of population crosses and population topcrosses to inbred testers. Mean grain yield of population topcrosses was significantly higher than those of population crosses and the checks at $P < 0.05$ and $P < 0.01$, respectively. However, mean grain yield of population crosses was not significantly different from that of the checks. These results showed that population topcrosses gave higher mean grain yield than population crosses and indicated high potential of testcross hybrids. The population topcrosses can be also used as variety × line hybrids for the developing countries as suggested by Shlomi and Efron (1976).

The improvement for grain yield of populations per se, population crosses and population topcrosses was similar to that reported by Lambert (1984) who found the significant response for grain yield in populations per se and population crosses due to MRRS. However, only one population testcross showed significant increase in grain yield. Similarly, Stojšin and Kannenberg (1994a; 1994b) reported significant increase for yield in both populations per se. Landi and Frascaroli (1995) reported that one population gave a highly significant gain per cycle for populations per se. They also showed that C2 population cross yielded significantly higher than C1 and C0 population crosses, although significant difference between C1 and C0 population crosses was not found. The response for grain yield of population crosses and population testcrosses were also found by Menz Rademacher et al. (1999).

Table 4.14 Mean grain yield of C0, C1 and C2 populations compared with Suwan5(S)C4 (population check) from data combined over two locations in the 2005 early rainy season.

Entry	**Grain yield**	**Relative to C0**	**Relative to check**
	kg ha^{-1}	…………… %	……………
AC0	5,938	100.0	90.9
AC1	6,349	106.9	97.2
AC2	6,625	111.6	101.4
BC0	6,545	100.0	100.2
BC1	6,197	94.7	94.9
BC2	6,477	99.0	99.2
AC0 x BC0	7,029	100.0	107.6
AC1 x BC1	7,093	100.9	108.6
AC2 x BC2	7,200	102.4	110.2
AC0 x Ki 47	7,279	100.0	111.4
AC1 x Ki 47	8,007	110.0	122.6
AC2 x Ki 47	7,165	98.4	109.7
BC0 x Ki 46	7,589	100.0	116.2
BC1 x Ki 46	7,937	104.6	121.5
BC2 x Ki 46	8,150	107.4	124.8
Suwan5(S)C4 (Check)	6,532	-	100.0
LSD 0.05	726.47	-	-
LSD 0.01	979.07	-	-

4.1.6 Evaluation of C0, C1 and C2 populations per se and their population crosses according to Gardner-Eberhart Analysis II and Analysis III

Combined analyses of variance

Data for C0, C1 and C2 populations per se and their diallel crosses were analyzed using Gardner-Eberhart Analysis II and Analysis III to obtain the estimates of genetic effects including variety effects (v_i), variety heterosis effects (h_i), average heterosis ($\bar{h}$) and gca and sca effects.

Table 4.15 shows mean squares from combined analyses of variance for 10 traits from six populations per se and their 15 diallel crosses using Gardner-Eberhart Analysis II and Analysis III. Varieties from Analysis II were not significant for all traits. The partitioning of heterosis showed that specific heterosis was significant for grain yield, days to 50% anthesis and silking, ear height and grain moisture, while mean squares for gca were not significant for all traits. Thus, variation among the crosses for grain yield was due mainly to nonadditive effects. Mean squares of sca were higher than those of gca for grain yield, days to 50% silking, ear height, root lodging and foliar diseases. The ratio of sca:gca shown in Tables 4.6 and 4.15 indicated that sca effects were important for grain yield, days to 50% silking, ear height and foliar diseases.

Estimates of variety effects

Estimates of variety effects (v_i) from Gardner-Eberhart Analysis II for 10 traits are shown in Table 4.16. For grain yield, AC2 and BC2 populations gave positive variety effects which were higher than those of AC0 and AC1, and BC0 and BC1, respectively. AC1 gave negative variety effects but it was still higher than that of AC0, whereas BC1 gave negative variety effects and it was lower than that of BC0.

Table 4.15 Mean squares from Gardner-Eberhart Analysis II and Analysis III of 10 traits from six populations per se and their 15 diallel crosses, from data combined over two locations in the 2005 early rainy season.

			Days to 50%		Height		Lodging		Foliar	Grain	Grain
Source of variation	**df**	**Grain yield**	**Ant.**	**Silk.**	**Plant**	**Ear**	**Stalk**	**Root**	**dis.**	**moist.**	**shell.**
		$kg\ ha^{-1}$	d		cm		%		(1-5)	%	
Gardner-Eberhart Analysis II											
Varieties	5	645144.58	2.26	2.12	504.39	59.64	91.84	0.37	0.13	3.02	4.62
Heterosis	15	1095644.68 *	1.14 *	1.30 *	135.48	143.71 **	23.61	0.13	0.07	1.11	2.44
Average heterosis	1	6003727.55	0.04	0.42	700.97	679.95	15.33	0.00	0.00	0.04	9.92
Variety heterosis	5	392885.87	1.12	1.12	44.31	32.49	42.73	0.14	0.06	1.88	2.17
Specific heterosis	9	940723.70 *	1.28 *	1.50 *	123.30	145.92 *	13.91	0.13	0.09	0.80 *	1.75
Varieties x L	5	837023.83 **	2.67 **	2.71 **	110.63	21.85	68.25 *	0.50 *	0.06	2.14 **	4.04
Heterosis x L	15	318661.04	0.39	0.52	116.58	39.09	22.56	0.17	0.06	0.64	3.80
Average heterosis x L	1	743205.04	0.67	0.50	254.97	12.20	6.52	0.16	0.06	2.11	17.07 **
Variety heterosis x L	5	384702.70	0.47	0.64	119.21	56.76	40.81	0.16	0.02	1.06	2.40
Specific heterosis x L	9	234799.68	0.31	0.45	99.75	32.25	14.21	0.17	0.09	0.24	3.10
Gardner-Eberhart Analysis III											
Varieties	5	530301.53	1.96	2.25	152.36	25.08	72.78	0.39	0.16 *	2.22	1.50
Varieties vs. Crosses	1	6003727.55	0.04	0.42	700.97	679.95	15.33	0.00	0.00	0.04	9.92
Crosses	14	786082.71	1.33	1.32	220.81	117.75 **	31.01	0.12	0.06	1.47	3.01
GCA	5	507728.92	1.42	0.99	396.34	67.04	61.79	0.11	0.03	2.68	5.29
SCA	9	940723.70 *	1.28 *	1.50 *	123.30	145.92 *	13.91	0.13	0.09	0.80 *	1.75
Varieties x L	5	333829.19	2.05 *	2.29 *	116.01	54.82	50.12	0.31	0.02	1.21	3.76
(Varieties vs. Crosses) x L	1	743205.04	0.67	0.50	254.97	12.20	6.52	0.16	0.06	2.11	17.07 **
Crosses x L	14	468048.84 *	0.59	0.67	104.78	29.23	30.18	0.23	0.07	0.87	2.95
GCA x L	5	887897.34 **	1.09	1.05	113.83	23.80	58.94	0.35	0.05	1.99 **	2.68
SCA x L	9	234799.68	0.31	0.45	99.75	32.25	14.21	0.17	0.09	0.24	3.10
SCA : GCA		1.85	0.90	1.51	0.31	2.18	0.23	1.16	3.07	0.30	0.33

*, ** Significant at the 0.05 and 0.01 probability levels, respectively.

The results corresponded with the means of the populations per se shown in Table 4.14. This indicated that the improved populations showed the improvement of grain yield, especially AC2. AC2 also gave negative variety effects for ear height and foliar diseases which were lower than those of AC0, indicating the lower ear height and foliar diseases score of AC2. BC2 also gave negative variety effects for root lodging and foliar diseases, and gave positive variety effects for grain shelling, indicating the lower root lodging and foliar diseases score and higher grain shelling percentage of BC2 than BC0.

Table 4.16 Estimates of variety effects (v_i) from Gardner-Eberhart Analysis II of 10 traits from six populations per se and their 15 diallel crosses, from data combined over two locations in the 2005 early rainy season.

Populations	v_i									
	Grain yield	Days to 50% Ant.	Days to 50% Silk.	Height Plant	Height Ear	Lodging Stalk	Lodging Root	Foliar dis.	Grain moist.	Grain shell.
	kg ha^{-1}	d		cm		%		(1-5)	%	
AC0	-469.62	-0.69	-0.75	2.89	2.41	6.15 *	-0.11	0.26 **	-0.16	0.41
AC1	-91.27	0.14	0.25	-0.19	-2.86	-3.14	0.22	-0.07	-0.03	-0.85
AC2	374.88	0.64	0.75	4.61	-0.39	1.23	0.14	-0.15	1.07	0.13
BC0	129.07	-0.19	-0.42	-8.28	-0.49	-2.74	0.22	0.01	-0.24	-0.35
BC1	-136.20	-0.53	-0.42	-3.28	-1.02	0.43	-0.03	0.10	-0.77	0.40
BC2	193.13	0.64	0.58	4.26	2.34	-1.94	-0.44	-0.15	0.13	0.25
SE†	313.04	1.19	1.09	6.56	5.27	2.63	0.29	0.09	0.87	0.61

† Standard error.

*, ** Significant at the 0.05 and 0.01 probability levels, respectively.

Estimates of variety heterosis effects and average heterosis

Table 4.17 shows estimates of variety heterosis effects (h_i) and average heterosis ($\bar{h}$) of 10 traits according to Gardner-Eberhart Analysis II. For grain yield, AC2 gave negative variety heterosis effects and it was lower than those of AC0 and

AC1. AC1 also gave negative variety heterosis effects and it was lower than that of AC0. However, BC2 gave positive variety heterosis effects and it was higher than that of BC0 but was lower than that of BC1. The results indicated that AC1 and AC2 contributed less than the average to the overall heterosis, while BC1 and BC2 contributed more than the average. In contrast to the base populations, AC0 gave positive variety heterosis effects, whereas BC0 gave negative variety heterosis effects. The average heterosis for grain yield was positive and highly significant, indicating dominance of favorable alleles for grain yield.

Table 4.17 Estimates of variety heterosis effects (h_i) and average heterosis ($\bar{h}$) from Gardner-Eberhart Analysis II of 10 traits from six populations per se and their 15 diallel crosses, from data combined over two locations in the 2005 early rainy season.

Populations	h_i									
	Grain	Days to 50%		Height		Lodging		Foliar	Grain	Grain
	yield	Ant.	Silk.	Plant	Ear	Stalk	Root	dis.	moist.	shell.
	kg ha^{-1}	.... d		.... cm		%	....	(1-5)	....	% ....
AC0	84.89	0.22	0.32	-0.82	-0.89	-0.62	-0.03	-0.10	-0.50	-0.05
AC1	-2.30	-0.24	-0.26	1.99	2.64	2.58	-0.11	0.03	-0.02	0.00
AC2	-302.63	-0.19	-0.26	0.44	-0.69	-2.41	-0.07	0.05	-0.36	-0.77
BC0	-102.60	-0.24	-0.10	-1.98	-1.77	1.85	0.01	-0.06	0.01	0.35
BC1	195.46	0.51	0.44	-2.01	-0.62	-1.22	-0.01	-0.01	0.54	0.04
BC2	127.18	-0.07	-0.14	2.38	1.33	-0.19	0.20	0.09	0.33	0.43
$\bar{h}$	483.20 **	0.04	0.13	5.22	5.14	0.77	0.01	0.00	0.04	0.62
SE† for h_i	221.35	0.84	0.77	4.64	3.73	1.86	0.21	0.06	0.62	0.43
SE for $\bar{h}$	165.64	0.63	0.58	3.47	2.79	1.39	0.15	0.05	0.46	0.32

† Standard error.
** Significant at the 0.01 probability level.

Estimates of gca and sca effects

Estimates of gca and sca effects from Gardner-Eberhart Analysis III of 10 traits are shown in Table 4.18. For grain yield, AC2 gave negative gca effects which was higher than that of AC0 but lower than that of AC1, while BC2 gave positive gca effects which was higher than those of BC0 and BC1. The results indicated that AC1 and AC2, and BC1 and BC2 had higher frequency of favorable alleles for grain yield than AC0 and BC0, respectively. Also, the results indicated that the MRRS with use of inbred lines as testers was effective in improving gca effects for grain yield of the populations per se, especially for populations of B. Similar results were reported by Zambezi et al. (1986) who compared estimates of gca effects obtained by using inbred lines and broad-base populations as testers. They found that inbred testers were as effective as broad-base populations for the improvement of gca as well as sca in maize. AC2 also showed the improvement for gca effects for ear height, stalk lodging percentage and foliar diseases score, while BC2 also showed the improvement for gca effects for stalk lodging percentage, root lodging score and grain shelling percentage. Estimates of sca effects for grain yield showed that all population crosses of A × B gave positive sca effects except the AC0 × BC2 cross. In addition, BC0 × BC1 cross gave the highest positive sca effects. The results indicated good combining ability between A and B populations and signified the potential of interpopulation hybrids. BC0 × BC1 also gave significantly negative sca effects for foliar diseases at $P < 0.05$.

Table 4.18 Estimates of gca and sca effects from Gardner-Eberhart Analysis III of 10 traits of six populations per se and their 15 diallel crosses, from data combined over two locations in the 2005 early rainy season.

Traits	Populations	AC0	AC1	AC2	BC0	BC1	BC2	GCA effects
			SCA effects					
Grain yield (kg ha^{-1})	AC0		-280.42	-321.15	257.50	390.42	-46.36	-149.92
	AC1			-434.67	232.47	166.49	316.14	-47.93
	AC2				138.12	341.33	276.37	-115.19
	BC0					490.09	-138.00	-38.07
	BC1						-408.15	127.36
	BC2							223.75
	SE† (gca effects)		156.52					
	SE (sca effects)		265.62					
Days to 50% anthesis (d)	AC0		-0.11	0.77	-0.28	0.14	-0.53	-0.13
	AC1			0.14	0.10	-0.15	0.02	-0.17
	AC2				-0.03	-0.44	-0.44	0.13
	BC0					0.15	0.35	-0.33
	BC1						0.60	0.25
	BC2							0.25
	SE (gca effects)		0.59					
	SE (sca effects)		1.01					
Days to 50% silking (d)	AC0		-0.18	0.90	-0.18	-0.06	-0.48	-0.06
	AC1			0.32	0.07	-0.14	-0.06	-0.14
	AC2				-0.35	-0.39	-0.48	0.11
	BC0					-0.03	0.44	-0.31
	BC1						0.57	0.24
	BC2							0.15
	SE (gca effects)		0.55					
	SE (sca effects)		0.93					
Plant height (cm)	AC0		-4.55	-3.45	5.37	-1.62	4.26	0.62
	AC1			-2.44	1.41	4.15	1.43	1.90
	AC2				-0.04	5.94	-0.01	2.74
	BC0					4.76	-1.97	-6.12
	BC1						-3.71	-3.65
	BC2							4.51
	SE (gca effects)		3.28					
	SE (sca effects)		5.56					
Ear height (cm)	AC0		-2.59	-5.86	5.52	-1.16	4.08	0.31
	AC1			-3.25	1.32	0.61	3.90	1.21
	AC2				1.86	7.05	0.19	-0.88
	BC0					3.52	-5.19	-2.01
	BC1						-2.99	-1.13
	BC2							2.51
	SE (gca effects)		2.64					
	SE (sca effects)		4.47					

Table 4.18 (continued)

Traits	Populations	AC0	AC1	AC2	BC0	BC1	BC2	GCA effects
			SCA effects					
Stalk lodging (%)	AC0		1.74	-2.17	0.69	0.19	-0.45	2.46
	AC1			0.05	-2.23	1.24	-0.80	1.01
	AC2				1.77	-0.71	1.06	-1.80
	BC0					0.57	0.34	0.48
	BC1						-0.15	-1.00
	BC2							-1.15
	SE (gca effects)		1.31					
	SE (sca effects)		2.23					
Root lodging (1-5)	AC0		-0.03	-0.12	-0.08	0.15	0.07	-0.08
	AC1			0.05	0.01	-0.10	0.07	0.00
	AC2				-0.08	-0.01	0.15	0.00
	BC0					-0.20	-0.05	0.13
	BC1						-0.24	-0.02
	BC2							-0.02
	SE (gca effects)		0.15					
	SE (sca effects)		0.25					
Foliar diseases (1-5)	AC0		-0.02	0.00	-0.14	0.03	0.13	0.03
	AC1			0.13	-0.02	-0.02	-0.08	-0.01
	AC2				-0.08	-0.08	0.03	-0.03
	BC0					-0.19 *	0.05	-0.05
	BC1						-0.12	0.03
	BC2							0.01
	SE (gca effects)		0.05					
	SE (sca effects)		0.08					
Grain moisture (%)	AC0		-0.36	0.05	0.31	0.43	-0.43	-0.58
	AC1			-0.04	0.11	0.01	0.28	-0.03
	AC2				-0.23	0.24	-0.02	0.17
	BC0					0.52	0.33	-0.11
	BC1						-0.17	0.16
	BC2							0.39
	SE (gca effects)		0.44					
	SE (sca effects)		0.74					
Grain shelling (%)	AC0		0.80	-0.35	-0.19	-0.22	-0.04	0.15
	AC1			-0.71	-0.42	0.06	0.27	-0.43
	AC2				0.24	0.34	0.49	-0.70 *
	BC0					-0.46	-0.09	0.18
	BC1						-0.63	0.25
	BC2							0.56
	SE (gca effects)		0.30					
	SE (sca effects)		0.52					

† Standard error.

* Significant at the 0.05 probability level.

4.2 Hybrid development

The results of each cycle of selection were divided into two parts, i.e., (1) yield evaluation for all hybrids developed from each cycle and (2) estimation of components of genetic variances and gca and sca effects from 100 interpopulation hybrids developed from each cycle according to Design II. The 10 traits collected were grain yield, days to 50% anthesis and silking, plant and ear heights, stalk and root lodging, foliar diseases, grain moisture and grain shelling. Data for other six traits, including seedling vigor, husk cover, plant and ear aspects, rotten ears and ears plant^{-1}, are shown in Appendix Tables 1C-11C. For rating score of corn borer infestation and degree of leaf angle are shown in Appendix Tables 6C-11C.

Cycle 0

4.2.1 Yield evaluation for all C0 hybrids

Combined analyses of variance

Twenty-five C0-S_4 lines each, which corresponded to the 25 top-yielders of C0-S_1 testcrosses and the lines used for recombination to form C1 populations, were crossed with inbred tester (25 AC0-S_4 $\times$ Ki 47 and 25 BC0-S_4 $\times$ Ki 46) to produce a total of 50 C0 testcross hybrids. Ten C0-S_4 lines each, which corresponded to the 10 top-yielders of C0-S_1 testcrosses and were included in the lines used for recombination, were crossed between groups in a factorial manner (10 AC0-S_4 $\times$ 10 BC0-S_4) to produce 100 C0 interpopulation hybrids. The 150 C0 hybrids and six hybrids, including KSX 4451, KSX 4453, BIG 949, PIONEER 30A30, KSX 4452 (Suwan 4452) and Suwan 3851, were evaluated at two locations in the 2002 late rainy season using a 12 $\times$ 13 simple rectangular lattice design. The objective of the experiments was to evaluate yield potential of C0 hybrids developed from the selected 25 C0 lines.

Mean squares from combined analyses of variance of 10 traits of the C0 hybrids are shown in Table 4.19. Highly significant differences ($P < 0.01$) were detected among locations for all traits. Grain yield was highly significant for both of C0-S_4 testcross hybrids and C0-S_4 interpopulation hybrids. The comparisons between AC0-S_4 testcross hybrids vs. BC0-S_4 testcross hybrids were highly significant for plant and ear heights, grain moisture and grain shelling, and significant ($P < 0.05$) for grain yield. The C0-S_4 testcross hybrids vs. C0-S_4 interpopulation hybrids was highly significant for grain yield, days to 50% anthesis and silking, plant height and stalk and root lodging, and significant for foliar diseases. The comparisons between C0 hybrids vs. checks showed a highly significant difference for root lodging, and significant differences for stalk lodging and grain moisture. However, no significant differences were detected for all traits evaluated for interaction of treatments with locations.

Means of hybrids

Mean grain yield of the top 10 C0 hybrids was 7,144 kg ha^{-1} or 122.2% of the hybrid check, Suwan 3851 (Table 4.20). Mean grain yield of the top 10 AC0 testcross hybrids, the top 10 BC0 testcross hybrids and the top 10 C0 interpopulation hybrids were 6,984 kg ha^{-1}, 6,737 kg ha^{-1} and 6,756 kg ha^{-1}, or 119.5%, 115.3% and 115.6% of the check, respectively. No significant differences were detected between mean grain yield of the top 10 AC0 testcross hybrids, the top 10 BC0 testcross hybrids, the top 10 C0 interpopulation hybrids and the six hybrid checks.

Means of 10 traits of the top 10 C0 hybrids of each group are shown in Table 4.21. The top 10 yielding C0 hybrids included five AC0 testcross hybrids, two BC0 testcross hybrids and three C0 interpopulation hybrids. The top 10 C0 hybrids showed that the testcross hybrids were predominant, especially testcross hybrids from AC0-$S_4 \times$ Ki 47, indicating that superior lines developed from the improved populations

Table 4.19 Mean squares from analyses of variance of 10 traits of C0 hybrids from data combined over two locations in the 2002 late rainy season.

			Days to 50%		Height		Lodging		Foliar	Grain	Grain
Source of variation	**df**	**Grain yield**	**Ant.**	**Silk.**	**Plant**	**Ear**	**Stalk**	**Root**	**dis.**	**moist.**	**shell.**
		kg ha^{-1}	d		cm		%		(1-5)	%	
Locations (L)	1	503479238.55 **	1447.39 **	1163.48 **	113219.10 **	9538.32 **	62.07 **	10.14 **	22.62 **	118.29 **	735.31 **
Treatments (T)	155	894880.60 **	2.48 **	3.22 **	167.11 **	111.22 **	7.82 *	0.19 **	0.06 *	5.12 **	9.67 **
C0 hybrids	149	881538.64 **	2.43 **	3.15 **	156.42 **	110.89 **	7.96	0.19 **	0.06 **	4.45 **	9.77 **
C0-S_4 TCHs†	49	734505.74 **	1.30 **	1.57 **	172.01 **	155.17 **	2.78	0.11	0.04	5.75 **	6.59 **
AC0-S_4 TCHs	24	744463.41 **	1.35 **	1.11 **	88.38 *	95.71 **	3.12	0.12	0.03	2.15	5.80 **
BC0-S_4 TCHs	24	687824.12 **	1.31 **	2.10 **	123.73 **	56.53 **	2.49	0.10	0.05	5.09 **	4.72 **
AC0-S_4 TCHs vs. BC0-S_4 TCHs	1	1615880.80 *	0.12	0.09	3338.07 **	3949.51 **	1.79	0.01	0.02	108.07 **	70.17 **
C0-S_4 IPHs‡	99	704326.22 **	2.31 **	2.55 **	129.99 **	90.07 **	10.14 **	0.21 **	0.07 **	3.85 **	11.43 **
C0-S_4 TCHs vs. C0-S_4 IPHs	1	25630180.12 **	69.29 **	138.64 **	2009.52 **	3.37	45.95 **	2.99 **	0.25 *	0.05	1.00
Checks	5	829785.74	1.65	3.24	72.89 *	118.17 **	1.21	0.16	0.04	9.26 **	8.04 *
C0 hybrids vs. Checks	1	3208307.37	14.28	13.63	2229.96	125.47	19.35 *	0.37 **	0.15	84.57 *	3.42
T x L	155	281303.52	0.35	0.41	46.18	18.23	5.71	0.08	0.04	1.49	1.27
C0 hybrids x L	149	282146.14	0.33	0.39	46.50	18.19	5.90	0.08	0.04	1.52	1.26
Checks x L	5	291522.03	0.67	0.87	9.86	9.50	1.21	0.09	0.08	0.75	1.40
(C0 hybrids vs. Checks) x L	1	104661.29	0.90	0.38	180.00	67.38	0.06	0.00	0.06	0.19	2.70
Pooled error	262	245595.50	0.49	0.62	52.12	26.88	8.93	0.12	0.05	1.92	1.49
CV (%)		8.99	1.04	1.12	3.15	3.97	135.94	15.48	6.40	4.73	1.42

† TCHs = testcross hybrids.

‡ IPHs = interpopulation hybrids.

*, ** Significant at the 0.05 and 0.01 probability levels, respectively.

Table 4.20 Grain yield of C0 hybrids compared with Suwan 3851 (hybrid check) from data combined over two locations in the 2002 late rainy season.

Entry	Grain yield Range	Grain yield Mean	Relative to check
	kg ha^{-1}		%
Total C0 hybrids	4,368-7,790	5,877	100.5
C0 testcross hybrids (TCHs)	4,675-7,790	6,290	107.6
AC0-S_4 x Ki 47	5,301-7,790	6,417	109.8
BC0-S_4 x Ki 46	4,675-6,991	6,163	105.4
C0 interpopulation hybrids (IPHs)	4,368-7,074	5,670	97.0
Top 10 C0-S_4 hybrids	6,873-7,790	7,144	122.2
Top 10 AC0-S_4 TCHs	6,418-7,790	6,984	119.5
Top 10 BC0-S_4 TCHs	6,378-6,991	6,737	115.3
Top 10 C0-S_4 IPHs	6,437-7,074	6,756	115.6
Hybrid checks	5,845-7,618	6,404	109.6
KSX 4452 (Suwan 4452)	7,618	7,618	130.3
Suwan 3851 (Check)	5,845	5,845	100.0

of MRRS could be used immediately to produce hybrids with the inbred testers if the testers are elite lines being used in commercial hybrid production (Horner et al., 1972; Russell et al., 1992; Menz Rademacher et al., 1999). Grain yield of eight out of the 10 hybrids was significantly higher than the hybrid check, Suwan 3851. However, the yield of top 10 C0 hybrids was not significantly higher than Suwan 4452, a new single-cross hybrid which had a higher yield than Suwan 3851.

For other traits, the top 10 C0 hybrids had significantly higher means for plant and ear heights than the check at $P < 0.01$. The top 10 AC0 testcross hybrids had higher means for plant and ear heights than the check at $P < 0.01$, while only mean for plant height of the top 10 BC0 testcross hybrids was higher than that of the check ($P < 0.01$). For the top 10 C0 interpopulation hybrids, means for days to 50% anthesis and plant height were higher than those of the check at $P < 0.01$.

Table 4.21 Means of 10 traits of the top 10 C0 hybrids of each group compared with Suwan 3851 (hybrid check) from data combined over two locations in the 2002 late rainy season.

Entry	Grain yield at 15% moist.	Relat. to check	Days to 50% Ant.	Days to 50% Silk.	Height Plant	Height Ear	Lodging Stalk	Lodging Root	Foliar dis.	Grain moist.	Grain shell.
	kg ha^{-1}	%	d		cm		%	(1-5)		%	
Top 10 C0 hybrids											
AC0-S_4-88 x Ki 47	7,790	133	56	56	223	119	1	1.2	3.1	28.11	80.57
AC0-S_4-72 x Ki 47	7,471	128	57	57	235	132	1	2.1	3.1	27.76	82.06
AC0-S_4-96 x Ki 47	7,410	127	57	57	224	111	0	1.9	3.1	26.41	83.12
AC0-S_3-180 x Ki 47	7,105	122	56	57	206	111	0	1.9	3.0	27.63	80.93
AC0-S_4-159 x BC0-S_4-250	7,074	121	57	57	229	115	1	1.9	3.4	26.28	81.75
BC0-S_4-90 x Ki 46	6,991	120	56	56	221	110	4	2.2	3.3	26.70	80.33
AC0-S_4-228 x Ki 47	6,927	119	56	56	221	111	3	1.8	3.2	26.09	81.94
AC0-S_4-204 x BC0-S_4-47	6,923	118	56	57	225	111	3	2.0	3.2	25.56	78.99
AC0-S_4-159 x BC0-S_4-47	6,878	118	56	57	222	107	12	1.3	3.2	27.37	80.40
BC0-S_4-296 x Ki 46	6,873	118	57	58	217	103	0	1.6	3.1	25.69	80.01
Mean	7,144	122	56	57	222	113	2	1.8	3.2	26.76	81.01
Top 10 AC0 testcross hybrids											
AC0-S_4-88 x Ki 47	7,790	133	56	56	223	119	1	1.2	3.1	28.11	80.57
AC0-S_4-72 x Ki 47	7,471	128	57	57	235	132	1	2.1	3.1	27.76	82.06
AC0-S_4-96 x Ki 47	7,410	127	57	57	224	111	0	1.9	3.1	26.41	83.12
AC0-S_3-180 x Ki 47	7,105	122	56	57	206	111	0	1.9	3.0	27.63	80.93
AC0-S_4-228 x Ki 47	6,927	119	56	56	221	111	3	1.8	3.2	26.09	81.94
AC0-S_4-159 x Ki 47	6,760	116	56	56	218	115	0	1.5	2.8	28.38	78.91
AC0-S_4-86 x Ki 47	6,666	114	55	56	213	107	2	1.8	3.2	26.84	81.85
AC0-S_4-136 x Ki 47	6,652	114	56	57	222	113	3	2.1	3.3	25.06	82.25
AC0-S_4-14 x Ki 47	6,639	114	57	57	226	117	1	1.7	3.2	27.83	80.60
AC0-S_4-57 x Ki 47	6,418	110	56	56	223	120	0	1.6	3.1	28.11	79.33
Mean	6,984	119	56	56	221	116	1	1.8	3.1	27.22	81.16
Top 10 BC0 testcross hybrids											
BC0-S_4-90 x Ki 46	6,991	120	56	56	221	110	4	2.2	3.3	26.70	80.33
BC0-S_4-296 x Ki 46	6,873	118	57	58	217	103	0	1.6	3.1	25.69	80.01
BC0-S_4-250 x Ki 46	6,870	118	57	57	209	108	1	2.0	3.3	24.11	81.12
BC0-S_4-184 x Ki 46	6,828	117	56	56	201	95	0	1.5	3.1	24.96	80.88
BC0-S_4-71 x Ki 46	6,805	116	55	55	205	105	0	2.0	2.9	27.34	78.44
BC0-S_4-140 x Ki 46	6,775	116	57	58	211	103	0	1.5	2.9	25.83	79.47
BC0-S_4-115 x Ki 46	6,681	114	57	57	216	109	0	1.6	3.2	24.49	75.07
BC0-S_4-47 x Ki 46	6,646	114	56	58	207	103	3	1.8	3.3	24.45	78.56
BC0-S_4-186 x Ki 46	6,521	112	56	57	211	98	2	2.1	3.1	23.96	80.97
BC0-S_4-49 x Ki 46	6,378	109	57	56	215	109	2	1.5	3.2	27.61	76.95
Mean	6,737	115	56	57	211	104	1	1.8	3.1	25.51	79.18

Table 4.21 (continued)

Entry	Grain yield at 15% moist.	Relat. to check	Days to 50% Ant.	Days to 50% Silk.	Height Plant	Height Ear	Lodging Stalk	Lodging Root	Foliar dis.	Grain moist.	Grain shell.
	kg ha^{-1}	%	d		cm		%	(1-5)		%	
Top 10 C0 interpopulation hybrids											
AC0-S_4-159 x BC0-S_4-250	7,074	121	57	57	229	115	1	1.9	3.4	26.28	81.75
AC0-S_4-204 x BC0-S_4-47	6,923	118	56	57	225	111	3	2.0	3.2	25.56	78.99
AC0-S_4-159 x BC0-S_4-47	6,878	118	56	57	222	107	12	1.3	3.2	27.37	80.40
AC0-S_4-159 x BC0-S_4-296	6,864	117	56	56	220	110	1	1.5	2.9	27.85	81.11
AC0-S_4-159 x BC0-S_4-90	6,803	116	57	57	230	115	1	1.8	3.2	27.22	82.44
AC0-S_4-146 x BC0-S_4-184	6,734	115	57	58	218	101	0	1.9	3.1	23.88	83.16
AC0-S_4-159 x BC0-S_4-140	6,725	115	57	58	224	113	1	1.7	2.7	26.60	81.67
AC0-S_4-159 x BC0-S_4-184	6,648	114	57	57	213	100	0	1.6	2.9	25.99	82.76
AC0-S_4-4 x BC0-S_4-250	6,474	111	57	57	211	106	1	2.0	3.6	24.95	81.25
AC0-S_4-146 x BC0-S_4-296	6,437	110	57	58	225	113	3	1.7	3.1	25.31	79.92
Mean	6,756	116	57	57	222	109	2	1.7	3.1	26.10	81.34
Hybrid checks											
KSX 4451	6,090	104	55	56	208	111	1	2.0	3.1	29.53	78.80
KSX 4453	6,477	111	56	57	206	106	0	1.9	3.1	26.49	77.94
BIG 949	5,975	102	56	57	204	96	0	1.6	2.9	31.90	80.62
PIONEER 30A30	6,419	110	54	54	197	97	0	1.3	3.1	27.08	83.47
KSX 4452 (Suwan 4452)	7,618	130	56	57	206	115	0	1.5	2.9	28.96	81.27
Suwan 3851 (Check)	5,845	100	55	56	193	101	2	1.9	3.2	26.42	79.20
Mean	6,404	110	55	56	202	104	1	1.7	3.1	28.40	80.22
LSD 0.05	1,047.70		1.16	1.26	13.42	8.43	4.72	0.57	0.40	2.41	2.23
LSD 0.01	1,383.20		1.53	1.66	17.72	11.13	6.23	0.76	0.53	3.18	2.94

4.2.2 Analyses for genetic variances and gca and sca effects from 100 C0 interpopulation hybrids according to Design II

Combined analyses of variance

Data of 100 C0 interpopulation hybrids (10 AC0-S_4 × 10 BC0-S_4) were analyzed according to Design II to obtain estimates of components of genetic variances and gca and sca effects.

Mean squares from combined analyses of variance of 10 traits of 100 C0 interpopulation hybrids are shown in Table 4.22. For grain yield, general combining ability (gca) effects for females (A) and males (B) were not significantly different, while specific combining ability (sca) effects was highly significant, indicating that sca was important for this trait. Interaction of gca of both females and males with locations were highly significant, but interaction of sca with locations was not. Mean squares for gca for female lines were highly significant for days to 50% anthesis and silking, ear height and grain shelling, and significant for plant height, while those of gca for male lines were highly significant for days to 50% anthesis and grain shelling, and significant for ear height and root lodging. Mean squares for sca showed highly significant differences for days to 50% silking, ear height and grain shelling, and significant differences for days to 50% anthesis, plant height and foliar diseases. The data indicated that female (AC0) was more important than male (BC0) in contributing genetic variation of gca for many traits, such as days to 50% anthesis and silking, plant and ear heights and grain shelling. In addition, sca was also important for the expression of many traits such as days to 50% anthesis and silking, plant and ear heights, foliar diseases and grain shelling. Interaction of gca with locations was significant, while no significant differences were observed for all traits evaluated for interaction of sca with locations.

Estimates of components of genetic variances

Estimates of components of genetic variances of 10 traits of 100 C0 interpopulation hybrids are shown in Table 4.23. For grain yield, variance for gca for females (σ^2_f) was greater than that for males (σ^2_m) indicating that the higher additive gene effect was provided by female parents. For the same trait, variance for gca for females was about 1.53 and 2.20 times greater than variances for gca for males and for sca (σ^2_{fm}), showing that in the base populations, additive gene effect was predominant especially in AC0 population. In terms of genetic variances, it was found that in the

Table 4.22 Mean squares from analyses of variance of 10 traits of 100 C0 interpopulation hybrids from data combined over two locations in the 2002 late rainy season.

			Days to 50%		Height		Lodging		Foliar	Grain	Grain
Source of variation	**df**	**Grain yield**	**Ant.**	**Silk.**	**Plant**	**Ear**	**Stalk**	**Root**	**dis.**	**moist.**	**shell.**
		kg ha^{-1}	d		cm		%	(1-5)		%	
Locations (L)	1	710929707.68	1693.32	1421.29	156183.04	13545.47	81.31	14.44	26.52	122.14	914.19
Replications/L	2	787828.67	3.36	3.38	573.21	1022.27	7.36	0.51	0.11	11.44	28.43
Varieties (V)	99	1375993.69	4.96	5.45	264.64	204.54	21.06	0.41	0.16	7.77	23.23
Females (A)	9	6234780.45	38.19 **	35.36 **	1303.63 *	900.18 **	50.81	1.43	0.29	36.07	104.56 **
Males (B)	9	4237459.92	5.90 **	6.21	852.91	800.20 *	50.41	1.68 *	0.86	22.12	114.46 **
A x B	81	518187.80 **	1.17 *	2.04 **	83.84 *	61.06 **	14.50	0.15	0.07 *	3.03	4.06 **
L x V	99	590733.42	0.84	1.11	93.63	56.84	16.16	0.23	0.09	3.79	2.49
L x A	9	2052045.95 **	1.59 *	2.40 **	328.52 **	261.79 **	24.75	0.55 **	0.24 **	10.31 **	3.56
L x B	9	1892008.45 **	0.63	2.04 *	219.68 **	67.87 *	35.31 **	0.26	0.37 **	9.42 **	7.61 **
L x (AB)	81	283779.24	0.78	0.86	53.53	32.84	13.08	0.19	0.05	2.44	1.80
Pooled error	198	259053.96	0.61	0.83	69.52	43.20	12.17	0.15	0.07	2.07	1.46

*, ** Significant at the 0.05 and 0.01 probability levels, respectively.

base populations, ratio of σ^2_D/σ^2_A was about 0.27. For other traits, variance for gca for females was greater than variance for gca for males and sca except root lodging, foliar diseases and grain shelling.

Table 4.23 Estimates of components of genetic variances of 10 traits of 100 C0 interpopulation hybrids from data combined over two locations in the 2002 late rainy season.

Variance	Grain yield	Days to 50% Ant.	Days to 50% Silk.	Height Plant	Height Ear	Lodging Stalk	Lodging Root	Foliar dis.	Grain moist.	Grain shell.
	kg ha^{-1}	d		cm		%		(1-5)	%	
σ^2_f	142914.82	0.93	0.83	30.49	20.98	0.91	0.03	0.01	0.83	2.51
σ^2_m	92981.80	0.12	0.10	19.23	18.48	0.90	0.04	0.02	0.48	2.76
σ^2_{fm}	64783.46	0.14	0.30	3.58	4.46	0.58	0.00	0.00	0.24	0.65
σ^2_A	235896.62	1.04	0.94	49.72	39.46	1.81	0.07	0.03	1.30	5.27
σ^2_D	64783.46	0.14	0.30	3.58	4.46	0.58	0.00	0.00	0.24	0.65
σ^2_D/σ^2_A	0.27	0.13	0.32	0.07	0.11	0.32	0.00	0.02	0.18	0.12

Estimates of gca and sca effects

Table 4.24 presents the estimates of gca and sca effects of 10 traits of 100 C0 interpopulation hybrids. For grain yield, three C0 female lines (A7, A4 and A6) gave significantly positive gca effects at $P < 0.01$. In the group of C0 male lines, two lines (B2 and B9) and three lines (B8, B10 and B4) gave significantly positive gca effects at $P < 0.01$ and $P < 0.05$, respectively. Among 100 C0 interpopulation hybrids, two hybrids (A8 × B2 and A1 × B9) and four hybrids (A4 × B3, A8 × B5, A6 × B8 and A5 × B9) gave significantly positive sca effects at $P < 0.01$ and $P < 0.05$, respectively.

In addition, the C0 lines and hybrids also gave significant gca and sca effects, respectively, for other traits. A7 line gave significantly negative gca effects for days to 50% anthesis and silking ($P < 0.01$; Table 4.24) and root lodging ($P < 0.01$), and significantly positive gca effects for grain shelling ($P < 0.01$). A4 line gave significantly negative gca effects for ear height ($P < 0.01$), and significantly positive gca effects for grain shelling ($P < 0.01$). A6 line gave significantly negative gca effects for grain moisture ($P < 0.01$).

B2 line gave significantly negative gca effects for days to 50% anthesis ($P < 0.01$; Table 4.24). B9 line gave significantly negative gca effects for grain moisture ($P < 0.01$), and significantly positive gca effects for grain shelling ($P < 0.01$). B8 line gave significantly negative gca effects for plant and ear heights ($P < 0.01$), stalk lodging ($P < 0.01$) and foliar diseases ($P < 0.01$), and significantly positive gca effects for grain shelling ($P < 0.01$). B10 line gave significantly negative gca effects for days to 50% anthesis and silking ($P < 0.05$), ear height ($P < 0.05$) and stalk and root lodging ($P < 0.05$), and significantly positive gca effects for grain shelling ($P < 0.01$). B4 line gave significantly positive gca effects for grain shelling ($P < 0.01$).

A1 × B9 gave significantly negative sca effects for days to 50% silking ($P < 0.05$; Table 4.24), and significantly positive sca effects for grain shelling ($P < 0.01$). A6 × B8 gave significantly positive sca effects for grain shelling ($P < 0.05$).

From the results, A8 × B2 or AC0-S_4-204 × BC0-S_4-47 was the one included in the top 10 C0 hybrids and yielded higher than the check, Suwan 3851 ($P < 0.05$). It had higher plant and ear heights than the check at $P < 0.01$ and $P < 0.05$, respectively (Table 4.21). A6 × B8 or AC0-S_4-146 × BC0-S_4-184 and A1 × B9 or AC0-S_4-4 × BC0-S_4-250 were included in the top 10 C0 interpopulation hybrids. A6 × B8 had more days to 50% anthesis and silking and higher plant height than the check at $P < 0.01$, but lower grain moisture ($P < 0.05$) and higher grain shelling percentage ($P < 0.01$). A1 × B9 had more days to 50% anthesis ($P < 0.01$), higher plant height ($P < 0.01$) and higher foliar diseases score ($P < 0.05$) than the check. In addition, one female line (A6) and three male lines (B2, B8 and B9) which were components of the three hybrids also gave significantly positive gca effects for grain yield (Table 4.24). Among the four lines, B8 and B9 also had high yield which were not significantly different from Ki 47 (Table 4.32).

Cycle 1

4.2.3 Yield evaluation for all C1 hybrids and the selected C0 hybrids

Combined analyses of variance

Twenty-five C1-S_3 lines each, which corresponded to the 25 top-yielders of C1-S_1 testcrosses and the lines used for recombination to form C2 populations, were crosses with inbred tester (25 AC1-S_3 × Ki 47 and 25 BC1-S_3 × Ki 46) to produce a total of 50 C1 testcross hybrids. Ten C1-S_3 lines each, which corresponded to the 10 top-yielders of C1-S_1 testcrosses and were included in the lines used for recombination, were crossed between groups in a factorial manner (10 AC1-S_3 × 10 BC1-S_3) to produce 100 C1 interpopulation hybrids. For C0 hybrids, the top 10 AC0 testcross hybrids, the top 10 BC0 testcross hybrids and the top 10 C0 interpopulation hybrids were selected and reproduced in the same generation as the C1 hybrids, while the top 10 C0 hybrids were also produced in S_8 generation. The 150 C1 hybrids, 40 C0 hybrids and six hybrids, including NK 40, PAC 999, BIG 919, DK 888, KSX 4601 and Suwan 4452, were evaluated at two locations in the 2005 early rainy season using a 14 × 14 simple lattice design to evaluate yield potential of the C1 and selected C0 hybrids.

Mean squares from combined analyses of variance of 10 traits of the C0 and C1 hybrids are shown in Table 4.25. Highly significant differences were detected among locations for all traits, except for grain shelling which was not significant.

Table 4.24 Estimates of gca and sca effects of 10 traits of 100 C0 interpopulation hybrids from data combined over two locations in the 2002 late rainy season.

Traits	**Females†**	**Males‡**										**GCA effects of females**
		B1	**B2**	**B3**	**B4**	**B5**	**B6**	**B7**	**B8**	**B9**	**B10**	
		SCA effects										
Grain yield (kg ha^{-1})	A1	192.84	-426.75	-121.12	-14.54	-106.51	-131.86	-202.00	-163.30	816.10 **	157.14	-328.48 **
	A2	-248.16	42.30	150.19	-105.77	241.77	335.81	132.19	-485.85	429.13	-491.62	-72.59
	A3	72.15	-60.42	41.98	97.93	-151.35	-59.83	-131.20	495.12	-727.63 *	423.25	-37.37
	A4	151.41	-329.67	564.98 *	-3.66	-88.40	138.16	64.85	38.18	-640.87 *	105.02	422.78 **
	A5	13.63	-369.17	-289.54	284.16	-174.73	287.99	310.54	-286.69	513.54 *	-289.73	-597.26 **
	A6	116.42	-277.52	104.82	-663.85 *	117.38	-115.94	422.46	520.10 *	-293.78	69.90	386.10 **
	A7	-213.66	-14.54	-363.96	136.45	-43.57	-239.93	326.18	-86.37	313.52	185.88	714.92 **
	A8	78.96	922.83 **	-301.06	-254.80	543.11 *	-40.64	-107.38	147.75	-1046.24 **	57.48	-76.37
	A9	-29.38	482.20	269.93	142.64	-293.03	-159.02	-494.19	-460.75	407.31	134.28	-237.66 *
	A10	-134.22	30.74	-56.23	381.44	-44.67	-14.73	-321.47	281.81	228.92	-351.60	-174.07 *
	GCA effects of males	-634.55 **	376.68 **	-356.89 **	207.24 *	-93.67	-208.96 *	-31.16	238.09 *	282.09 **	221.13 *	
	SE§ (gca effects)	80.48										
	SE (sca effects)	254.49										
Days to 50% anthesis (d)	A1	-0.72	0.85 *	-0.90 *	0.53	0.15	-0.25	0.25	0.43	-0.70	0.35	0.27 *
	A2	1.08 *	0.40	-0.10	-0.17	0.45	0.05	-0.20	-1.02 *	-0.40	-0.10	-0.03
	A3	0.05	-0.62	0.38	0.05	-0.57	0.78	0.53	-0.30	0.08	-0.37	0.75 **
	A4	-0.07	-0.25	-0.25	-0.82 *	0.80 *	0.65	-0.85 *	-0.42	0.70	0.50	0.37 **
	A5	-0.40	0.43	-0.07	0.10	-0.52	-0.42	0.58	0.25	-0.62	0.68	-2.55 **
	A6	0.78	-0.65	0.35	0.28	0.15	-0.25	-0.75	-0.32	0.80 *	-0.40	0.52 **
	A7	-0.15	0.43	-0.32	0.10	-0.27	-0.42	0.08	0.50	0.38	-0.32	-0.55 **
	A8	0.28	-0.40	0.60	0.53	0.15	0.00	-0.25	0.18	0.05	-1.15 *	0.52 **
	A9	-0.12	-0.05	0.20	-0.37	-0.25	0.35	0.85 *	-0.22	-0.35	-0.05	0.67 **
	A10	-0.72	-0.15	0.10	-0.22	-0.10	-0.50	-0.25	0.93 *	0.05	0.85 *	0.02
	GCA effects of males	0.02	-0.55 **	0.20	0.27 *	-0.35 *	-0.20	0.80 **	0.12	0.00	-0.30 *	
	SE (gca effects)	0.12										
	SE (sca effects)	0.39										

Table 4.24 (continued)

Traits	Females	Males										GCA effects of females
		B1	B2	B3	B4	B5	B6	B7	B8	B9	B10	
		SCA effects										
Days to 50% silking (d)	A1	-1.02 *	1.06 *	-1.29 *	0.76	0.48	-0.57	0.34	1.36 *	-1.29 *	0.16	0.62 **
	A2	1.79 **	-0.14	0.26	0.06	0.78	-0.27	-0.62	-0.84	-0.49	-0.54	0.07
	A3	-0.47	-0.89	-0.24	0.56	-0.47	0.98 *	0.63	-0.34	0.76	-0.54	0.57 **
	A4	0.36	-0.57	-0.41	-0.62	0.86	0.56	-0.79	-0.02	0.59	0.03	0.24
	A5	-0.54	1.04 *	0.19	-0.52	-0.54	-0.59	0.56	0.34	-0.56	0.63	-2.36 **
	A6	0.09	-0.59	0.81	-0.39	0.34	-0.22	-0.81	-0.54	1.06 *	0.26	0.02
	A7	0.31	0.88	-0.22	-0.42	-0.19	-0.49	0.16	0.43	0.03	-0.52	-0.71 **
	A8	-0.16	-0.84	0.81	0.61	0.09	0.03	-0.56	-0.04	0.81	-0.74	0.52 **
	A9	0.68	0.26	-0.09	-0.54	-0.82	0.88	1.04 *	-0.94 *	-0.59	0.11	0.92 **
	A10	-1.04 *	-0.22	0.19	0.48	-0.54	-0.34	0.06	0.59	-0.31	1.14 *	0.14
	GCA effects of males	0.62 **	-0.21	-0.61 **	0.09	-0.38 *	-0.08	0.52 **	0.24	0.14	-0.31 *	
	SE (gca effects)	0.14										
	SE (sca effects)	0.46										
Plant height (cm)	A1	-3.03	-3.84	2.92	1.05	0.70	-0.12	1.26	3.80	-7.54	4.79	-3.91 *
	A2	-0.96	2.85	-1.51	-7.18	4.65	4.70	-5.29	5.04	0.40	-2.71	0.65
	A3	-6.65	2.04	-2.94	8.78 *	2.51	0.79	-0.88	6.53	-8.79 *	-1.40	0.96
	A4	6.45	-6.26	4.28	0.51	2.61	2.24	-1.60	-11.54 *	3.82	-0.52	4.36 **
	A5	1.02	-0.61	3.48	5.33	-1.46	-0.81	3.94	2.78	-6.34	-7.35	-9.59 **
	A6	2.14	-4.42	0.47	-3.97	3.68	-0.19	-1.74	-1.03	5.01	0.05	8.92 **
	A7	1.40	-3.04	3.23	1.45	-3.32	-6.94	3.32	-2.23	4.61	1.52	2.91 *
	A8	-2.72	1.72	-0.89	-8.66 *	0.19	0.81	4.20	-0.69	4.52	1.53	5.41 **
	A9	-4.66	5.60	-7.18	0.39	-0.38	2.87	1.01	1.22	-1.30	2.44	-4.03 **
	A10	7.02	5.93	-1.88	2.30	-9.19 *	-3.35	-4.21	-3.88	5.61	1.65	-5.68 **
	GCA effects of males	-2.56	0.88	6.49 **	7.14 **	-0.47	-5.09 **	0.77	-7.18 **	2.58	-2.56	
	SE (gca effects)	1.32										
	SE (sca effects)	4.17										

Table 4.24 (continued)

Traits	Females	Males										GCA effects of females
		B1	B2	B3	B4	B5	B6	B7	B8	B9	B10	
		SCA effects										
Ear height (cm)	A1	-0.16	-0.63	-0.46	1.00	2.00	-2.65	1.03	4.07	-5.44	1.24	1.85
	A2	-1.76	0.02	-5.44	-7.47 *	2.85	9.98 **	-4.07	4.42	4.09	-2.61	2.57 *
	A3	0.96	1.24	-0.97	3.37	2.99	-0.43	-3.73	2.26	-5.74	0.04	1.23
	A4	1.91	-2.06	3.63	1.07	3.44	3.40	-1.53	-10.86 **	4.83	-3.84	-3.35 **
	A5	1.10	-1.78	0.30	1.89	-0.59	-0.79	2.66	0.45	0.02	-3.25	-8.54 **
	A6	3.13	-0.70	1.07	-0.84	2.91	-4.64	-1.49	0.10	-2.83	3.28	3.19 **
	A7	-1.40	-3.62	6.17	-0.86	-4.37	-4.79	2.34	-0.92	3.57	3.88	-0.79
	A8	-3.05	2.35	-6.10	-3.51	-0.77	0.56	8.51 *	4.30	0.25	-2.52	2.86 *
	A9	-6.34	0.74	-1.97	1.75	-1.06	2.32	1.65	-1.71	0.13	4.49	7.10 **
	A10	5.59	4.46	3.76	3.60	-7.40 *	-2.95	-5.37	-2.09	1.11	-0.71	-6.13 **
	GCA effects of males	-1.14	-0.54	6.54 **	6.08 **	-1.79	-0.12	1.43	-9.24 **	1.32	-2.54 *	
	SE (gca effects)	1.04										
	SE (sca effects)	3.29										
Stalk lodging (%)	A1	-0.26	-2.63	1.71	-0.07	-0.60	1.98	-0.46	0.47	-1.28	1.12	-0.85
	A2	-0.04	-1.22	-1.06	2.01	-2.85	-2.00	0.96	1.29	2.63	0.28	0.12
	A3	-2.38	1.80	1.84	3.17	2.55	1.60	-1.95	-2.24	-2.20	-2.19	1.87 **
	A4	0.49	-0.69	-1.75	-2.33	3.06	0.27	0.26	0.00	1.23	-0.54	-0.37
	A5	1.26	-1.95	0.45	-1.80	-1.23	-1.58	2.39	1.88	0.00	0.58	-0.90
	A6	-1.17	1.36	0.35	1.54	1.47	1.21	-1.27	-2.22	-1.59	0.31	1.84 **
	A7	0.94	8.70 **	-0.67	-1.84	-2.46	-2.22	-0.44	-0.11	-1.86	-0.04	-0.27
	A8	-0.54	-1.18	-1.62	0.18	-1.49	1.78	0.99	-0.45	2.76	-0.41	0.69
	A9	0.99	-1.95	-1.21	0.65	1.16	-0.38	-0.39	0.54	0.59	0.00	-0.91
	A10	0.71	-2.25	1.95	-1.49	0.37	-0.67	-0.08	0.84	-0.28	0.90	-1.22 *
	GCA effects of males	-1.00	1.36 *	0.01	1.19 *	1.21 *	0.37	-0.81	-1.74 **	0.61	-1.20 *	
	SE (gca effects)	0.55										
	SE (sca effects)	1.74										

Table 4.24 (continued)

Traits	Females	Males B1	B2	B3	B4	B5	B6	B7	B8	B9	B10	GCA effects of females
		SCA effects										
Root lodging (1-5)	A1	-0.08	0.16	0.01	0.12	0.29	0.11	-0.05	-0.15	-0.28	-0.13	-0.02
	A2	0.16	0.15	-0.13	0.24	-0.10	-0.28	-0.19	0.09	-0.04	0.11	-0.01
	A3	-0.17	-0.43 *	0.05	0.16	0.07	0.15	-0.14	0.26	0.14	-0.09	0.32 **
	A4	-0.04	-0.18	-0.08	0.03	0.45 *	-0.10	-0.14	-0.12	0.01	0.16	0.19 **
	A5	-0.18	0.06	0.29	-0.10	-0.32	-0.12	0.22	0.25	-0.13	0.02	-0.17 *
	A6	0.02	0.26	0.11	-0.03	-0.24	-0.04	-0.20	-0.05	0.32	-0.15	0.00
	A7	0.32	-0.19	0.04	-0.10	-0.06	0.14	0.10	-0.13	-0.13	0.02	-0.30 **
	A8	0.24	-0.15	-0.30	-0.19	-0.28	0.17	0.14	-0.09	0.29	0.19	0.17 *
	A9	-0.25	0.11	-0.04	0.07	-0.01	0.06	0.27	0.17	-0.08	-0.30	0.03
	A10	-0.03	0.21	0.06	-0.20	0.21	-0.09	0.00	-0.23	-0.10	0.17	-0.20 **
	GCA effects of males	-0.35 **	-0.09	-0.06	0.20 **	0.17 *	0.09	-0.12	-0.02	0.35 **	-0.17 *	
	SE (gca effects)	0.06										
	SE (sca effects)	0.19										
Foliar diseases (1-5)	A1	0.12	-0.26	0.13	-0.07	-0.30 *	0.16	-0.09	0.04	0.17	0.11	-0.12 *
	A2	-0.15	0.11	-0.13	-0.08	-0.18	0.02	0.14	0.16	0.16	-0.03	0.02
	A3	-0.02	0.11	-0.01	0.04	0.19	-0.11	0.02	-0.10	-0.10	-0.03	0.02
	A4	-0.04	0.08	-0.03	0.02	0.04	-0.01	0.12	-0.12	-0.12	0.07	0.04
	A5	0.08	-0.17	0.09	0.02	0.04	0.12	-0.13	0.00	0.00	-0.06	0.17 **
	A6	-0.16	-0.03	0.11	0.03	0.18	0.01	-0.12	0.14	-0.11	-0.04	0.03
	A7	0.06	-0.07	0.07	0.12	0.14	-0.16	-0.28 *	0.11	0.11	-0.08	-0.06
	A8	0.11	0.11	-0.01	-0.21	-0.18	0.02	0.02	0.03	0.03	0.09	-0.11 *
	A9	-0.07	-0.07	-0.18	-0.01	0.14	-0.03	0.22	0.11	-0.02	-0.08	-0.06
	A10	0.08	0.21	-0.03	0.14	-0.08	-0.01	0.12	-0.37 *	-0.12	0.07	0.04
	GCA effects of males	0.04	0.04	0.16 **	-0.02	0.08	-0.12 *	-0.12 *	-0.26 **	0.25 **	-0.07	
	SE (gca effects)	0.04										
	SE (sca effects)	0.13										

Table 4.24 (continued)

Traits	Females	Males										GCA effects of females
		B1	B2	B3	B4	B5	B6	B7	B8	B9	B10	
		SCA effects										
Grain moisture (%)	A1	-0.14	0.06	-1.00	-0.02	-0.21	-0.34	0.35	0.78	0.06	0.46	0.29
	A2	0.55	0.97	0.65	-0.62	1.17	-0.55	0.06	-0.89	-1.08	-0.26	0.80 **
	A3	-1.10	-0.74	-1.57 *	0.94	-0.56	-0.10	0.28	1.55 *	1.43	-0.13	-0.46 *
	A4	-0.19	-0.09	-0.15	0.96	0.41	0.30	-0.55	-0.97	-0.25	0.53	-0.33
	A5	-0.38	0.07	-0.35	0.36	-0.90	0.07	0.51	0.05	-0.24	0.80	-1.10 **
	A6	0.32	-0.45	-0.78	-0.15	0.32	-1.08	0.20	0.08	1.04	0.51	-1.69 **
	A7	0.60	-0.23	3.44 **	0.15	-0.83	-0.80	-1.28	-1.10	0.18	-0.12	1.60 **
	A8	0.73	-0.36	0.68	-0.47	0.49	0.95	-0.52	0.67	-0.45	-1.72 *	0.31
	A9	0.14	0.35	0.52	-1.12	0.81	0.45	-0.05	0.62	-0.46	-1.26	0.02
	A10	-0.53	0.43	-1.43	-0.02	-0.68	1.11	0.99	-0.81	-0.24	1.18	0.57 *
	GCA effects of males	0.15	-0.04	1.14 **	-0.22	-1.12 **	0.28	0.54 *	-0.15	-1.23 **	0.66 *	
	SE (gca effects)	0.23										
	SE (sca effects)	0.72										
Grain shelling (%)	A1	0.85	-1.27 *	-0.58	0.53	-0.85	0.85	-2.04 **	-1.50 *	2.46 **	1.56 *	-2.61 **
	A2	-2.41 **	0.37	-0.22	1.50 *	-2.23 **	0.75	0.45	0.34	0.99	0.46	-1.84 **
	A3	0.79	0.09	0.08	-0.57	1.16	-1.74 *	-0.72	0.70	-0.40	0.61	0.75 **
	A4	0.20	0.82	0.16	0.13	0.35	-0.62	-0.16	-0.07	-0.75	-0.05	2.25 **
	A5	1.34 *	-0.98	0.17	-0.16	0.90	0.35	-0.68	-0.53	-0.13	-0.26	1.18 **
	A6	-0.73	0.31	-0.06	-0.89	0.35	0.92	0.34	1.44 *	-1.23 *	-0.44	-0.06
	A7	0.21	-0.13	0.31	0.48	0.81	-0.60	1.12	-0.61	-0.95	-0.64	1.38 **
	A8	-0.63	0.63	-0.78	-0.77	-0.43	0.93	0.94	1.10	-1.83 **	0.83	-0.54 *
	A9	-0.09	0.94	0.58	0.23	-0.58	-1.86 **	0.73	-0.39	0.52	-0.09	1.15 **
	A10	0.47	-0.78	0.35	-0.46	0.53	1.02	0.02	-0.49	1.33 *	-1.98 **	-1.67 **
	GCA effects of males	-2.03 **	-0.66 **	-3.18 **	0.98 **	0.06	0.15	-0.48 *	2.42 **	1.76 **	0.96 **	
	SE (gca effects)	0.19										
	SE (sca effects)	0.60										

† A = AC0-S_4, ‡ B = BC0-S_4, § Standard error.

*, ** Exceeds its standard error by two and three times, respectively.

Grain yield was not significant for C0 hybrids but it was significant for C1 hybrids. The comparisons between AC0-S_3 testcross hybrids vs. BC0-S_3 testcross hybrids showed highly significant differences for plant and ear heights, and a significant difference for grain shelling. The C0-S_3 testcross hybrids vs. C0-S_3 interpopulation hybrids was highly significant for plant and ear heights and stalk lodging, and significant for days to 50% silking and grain moisture. The C0-S_3 hybrids vs. C0-S_8 hybrids showed a highly significant difference for grain shelling, and a significant difference for plant height.

The comparisons between AC1-S_3 testcross hybrids vs. BC1-S_3 testcross hybrids showed highly significant differences for plant and ear heights and grain shelling, and significant differences for stalk lodging, foliar diseases and grain moisture. The C1-S_3 testcross hybrids vs. C1-S_3 interpopulation hybrids was highly significant for grain yield, days to 50% anthesis and silking, plant and ear heights, root lodging and grain shelling. Only grain shelling was significant for the comparisons between C0 and C1 hybrids vs. checks. Interaction of treatments with locations was significant only for days to 50% silking.

Means of hybrids

The comparison between mean grain yield of C0 and C1 hybrids in each group revealed that C1 hybrids yielded significantly higher than C0 hybrids for all hybrid groups (Table 4.26). The top 10 C1 hybrids (8,645 kg ha^{-1}) had higher mean grain yield than the top 10 C0 hybrids (7,878 kg ha^{-1}) for 9.7% at $P < 0.01$. The top 10 AC1 testcross hybrids (8,315 kg ha^{-1}) and the top 10 BC1 testcross hybrids (8,396 kg ha^{-1}) had higher mean grain yield than the top 10 AC0 testcross hybrids (7,927 kg ha^{-1}) and the top 10 BC0 testcross hybrids (7,674 kg ha^{-1}) for 4.9% ($P < 0.05$) and 9.4% ($P < 0.01$), respectively. Mean grain yield of the top 10 C1 interpopulation hybrids

Table 4.25 Mean squares from analyses of variance of 10 traits of C0 and C1 hybrids from data combined over two locations in the 2005 early rainy season.

Source of variation	df	Grain yield	Days to 50% Ant.	Days to 50% Silk.	Height Plant	Height Ear	Lodging Stalk	Lodging Root	Foliar dis.	Grain moist.	Grain shell.
		kg ha^{-1}	d		cm		%		(1-5)	%	
Locations (L)	1	78891998.33 **	692.45 **	602.54 **	113461.13 **	77478.76 **	628.11 **	74.59 **	9.41 **	825.99 **	0.21
Treatments (T)	195	587956.84	2.15 **	2.14 **	181.40 **	145.62 **	15.90 *	0.25 **	0.05 *	1.92 **	8.71 **
C0 hybrids	39	422807.26	1.83 *	2.02	151.81 **	141.58 **	23.78 **	0.29	0.06 *	1.44	7.27
C0-S_3 TCHs†	19	463785.49	1.17	1.70	127.31 **	93.30 **	14.66 *	0.43 *	0.05	1.03	7.23
AC0-S_3 TCHs	9	470527.51	0.56	1.57	57.79 **	36.69 *	23.03 **	0.57 *	0.04	0.80	4.65
BC0-S_3 TCHs	9	437357.34	1.72	1.86	132.48 **	88.87 **	5.59	0.33	0.07	1.32	8.12
AC0-S_3 TCHs vs. BC0-S_3 TCHs	1	640960.62	1.75	1.40	706.36 **	642.56 **	20.84	0.06	0.03	0.47	22.42 *
C0-S_3 IPHs‡	9	275339.08	0.88	1.37	70.44 **	208.91 **	50.62 **	0.13	0.04	1.66	6.42
C0-S_8 hybrids	9	539429.82	4.24 **	3.05	158.49 **	170.41 **	12.02	0.18	0.11 **	1.85 *	3.38
C0-S_3 hybrids vs. C0-S_8 hybrids	1	90994.60	0.12	0.79	78.90 *	5.27	3.36	0.35	0.03	0.78	50.23 **
C0-S_3 TCHs vs. C0-S_3 IPHs	1	253644.08	2.77	6.05 *	1362.63 **	330.01 **	81.71 **	0.11	0.00	4.46 *	7.94
C1 hybrids	149	609431.34 *	2.21 **	2.15 **	162.68 **	135.29 **	13.74	0.24 **	0.04	2.05 **	7.85 **
C1-S_3 TCHs	49	575898.83	1.44	1.31	142.54 **	129.30 **	9.91	0.21	0.03	2.25 **	7.01 **
AC1-S_3 TCHs	24	738088.46 *	1.35	1.36	57.36 *	33.96 *	15.94	0.24 *	0.03	2.65 **	4.02 *
BC1-S_3 TCHs	24	403859.22	1.57	1.27	136.58 **	139.27 **	1.94	0.17	0.03	1.74 *	5.98 **
AC1-S_3 TCHs vs. BC1-S_3 TCHs	1	812298.43	0.19	1.09	2329.99 **	2178.18 **	56.52 *	0.41	0.23 *	4.77 *	103.36 **
C1-S_3 IPHs	99	588019.58 *	2.17 **	1.73 **	128.97 **	133.28 **	15.69	0.24 **	0.04	1.95 **	7.92 **
C1-S_3 TCHs vs. C1-S_3 IPHs	1	4372287.74 **	44.93 **	84.66 **	4487.31 **	628.49 **	8.47	1.41 **	0.01	2.25	41.53 **
Checks	5	795703.10	3.54	3.63	361.99 *	418.71 **	8.95	0.26	0.06	2.08	12.25
C0 and C1 hybrids vs. Checks	1	2634409.33	0.81	0.09	3067.27	489.42	3.27	0.56	0.01	1.55	105.97 *
C0 hybrids vs. C1 hybrids	1	743906.55	0.04	0.04	334.62	132.75	77.48	0.01	0.35	1.35	77.76
T x L	195	467970.19	1.05	1.21 *	29.61	18.53	10.77	0.16	0.03	0.97	2.82
C0 hybrids x L	39	465218.44	1.03	1.45 *	17.14	15.32	7.48	0.21	0.03	0.87	4.67
C1 hybrids x L	149	422202.47	1.01	1.06	32.48	19.62	11.60	0.15	0.03	0.96	2.30
Checks x L	5	956828.19 *	1.32	2.21 *	37.98	16.24	9.69	0.20	0.04	1.55	4.30
(C0 and C1 hybrids vs. Checks) x L	1	4454049.92 **	6.75 **	6.77 **	70.44	3.60	3.14	0.01	0.00	2.69	0.20
(C0 hybrids vs. C1 hybrids) x L	1	964309.19	1.08	2.79	5.31	7.72	29.28	0.11	0.02	2.64	3.61
Pooled error	338	417066.50	0.89	0.85	32.46	27.20	13.27	0.19	0.04	0.97	3.38
CV (%)		8.88	2.01	2.12	2.20	3.03	95.83	17.16	6.53	4.80	2.03

† TCHs = testcross hybrids, ‡ IPHs = interpopulation hybrids.
*, ** Significant at the 0.05 and 0.01 probability levels, respectively.

(8,415 kg ha^{-1}) was higher than that of the top 10 C0 interpopulation hybrids (7,662 kg ha^{-1}) for 9.8% at P < 0.01. In addition, mean grain yield of each group of the top 10 hybrids from C0, including the top 10 C0 hybrids in S_8 generation, were not significantly different from each other, and the results were similar to C1.

Grain yield of nine, nine, eight and eight hybrids from the top 10 C0 hybrids in S_8 generation, the top 10 AC0 testcross hybrids, the top 10 BC0 testcross hybrids and the top 10 C0 interpopulation hybrids, respectively, were not significantly different from the hybrid check, Suwan 4452 (Table 4.27). However, grain yield of all hybrids from the top 10 AC1 testcross hybrids, the top 10 BC1 testcross hybrids and the top 10 C1 interpopulation hybrids were not significantly different from the check. Mean grain yield of the top 10 C0 hybrids was 92% of the check, while that of the top 10 C1 hybrids was 101% of the check. In addition, other C1 hybrids which had high yield as the check were 10 AC1 testcross hybrids, 15 BC1 testcross hybrids and 65 C1 interpopulation hybrids. Means of 18 traits, grain type and colors of stalk and midrib of the other high-yielding C1 hybrids are shown in Appendix Table 8C. These results showed that grain yield of the hybrids were not significantly different from the check, because Suwan 4452 was used as hybrid check in the experiments instead of Suwan 3851 whose seed production was terminated. However, Suwan 4452 had higher grain yield than Suwan 3851 for 47.3% (Table 4.12), 27.1% (Table 4.12) and 30.3% (Table 4.20), therefore, Suwan 4452 had higher grain yield than Suwan 3851 about 34.9%. As a result, all of the top 10 C1 hybrids also yielded significantly higher than Suwan 3851 at P < 0.01.

The top 10 yielding C1 hybrids which had high mean yield as the check, Suwan 4452, included three AC1 testcross hybrids, four BC1 testcross hybrids and three C1 interpopulation hybrids (Table 4.27). The types of hybrids were similar to that of the top 10 C0 hybrids. This confirms that potential hybrids are mostly the crosses of the selected line with inbred tester (testcross hybrids) rather than the crosses between the selected lines (interpopulation hybrids). The potential of testcross hybrids is probably due to the increase of sca between the lines and the inbred testers. Also, the inbred testers, Ki 46 and Ki 47 were well developed and are commercial inbred lines included in commercial hybrids (Aekatasanawan et al., 2001a; 2001b). However, among the top 10 C1 hybrids, the testcross hybrids of BC1-S_3 × Ki 46 were of larger proportion than AC1-S_3 × Ki 47, whereas among the top 10 C0 hybrids, the testcross hybrids of AC0-S_4 × Ki 47 were of larger proportion than BC0-S_4 × Ki 46. It was found previously that population topcrosses yielded higher than population crosses (Tables 4.5 and 4.14). These results signified the improvement for combining ability of both the selected lines and populations per se with their inbred tester.

The comparisons between means of other traits of each hybrid group and the check, Suwan 4452, showed that the top 10 C0 hybrids had higher plant height ($P < 0.05$) and foliar diseases score ($P < 0.05$) than the check, but lower grain moisture ($P < 0.05$). The top 10 C1 hybrids, the top 10 AC0 testcross hybrids and the top 10 AC1 testcross hybrids had only higher plant height ($P < 0.05$) than the check. The top 10 BC0 testcross hybrids had lower ear height ($P < 0.05$) than the check, but lower grain shelling percentage ($P < 0.05$). The top 10 BC1 testcross hybrids had lower ear height ($P < 0.05$) and lower grain moisture ($P < 0.05$) than the check, but lower grain shelling percentage ($P < 0.05$). The top 10 C0 interpopulation hybrids had higher plant height ($P < 0.01$) than the check, while the top 10 C1 interpopulation hybrids had higher plant height ($P < 0.01$) than the check, but lower grain moisture ($P < 0.05$).

Table 4.26 Grain yield of C0 and C1 hybrids compared with Suwan 4452 (hybrid check) from data combined over two locations in the 2005 early rainy season.

Entry	Grain yield		Relative to check
	Range	Mean	
	kg ha^{-1}		%
Total C0 and C1 hybrids	5,877-8,878	7,688	89.6
C0 hybrids	6,697-8,651	7,774	90.6
$C0\text{-}S_3$ testcross hybrids (TCHs)	6,737-8,651	7,800	91.0
$AC0\text{-}S_3$ x Ki 47	7,129-8,651	7,927	92.4
$BC0\text{-}S_3$ x Ki 46	6,737-8,214	7,674	89.5
$C0\text{-}S_3$ interpopulation hybrids (IPHs)	7,038-8,086	7,662	89.3
$C0\text{-}S_8$ hybrids	6,697-8,389	7,832	91.3
C1 hybrids	5,877-8,878	7,665	89.4
$C1\text{-}S_3$ TCHs	6,478-8,878	7,836	91.4
$AC1\text{-}S_3$ x Ki 47	6,478-8,878	7,746	90.3
$BC1\text{-}S_3$ x Ki 46	7,251-8,797	7,926	92.4
$C1\text{-}S_3$ IPHs	5,877-8,736	7,580	88.4
Hybrid checks	7,169-8,978	8,164	95.2
Suwan 4452 (Check)	8,576	8,576	100.0
			Relative to C0
			%
Top 10 $C0\text{-}S_3$ hybrids	7,184-8,450	7,878	100.0
Top 10 $C1\text{-}S_3$ hybrids	8,477-8,878	8,645	109.7
Top 10 $AC0\text{-}S_3$ TCHs	7,129-8,651	7,927	100.0
Top 10 $AC1\text{-}S_3$ TCHs	7,964-8,878	8,315	104.9
Top 10 $BC0\text{-}S_3$ TCHs	6,737-8,214	7,674	100.0
Top 10 $BC1\text{-}S_3$ TCHs	8,174-8,797	8,396	109.4
Top 10 $C0\text{-}S_3$ IPHs	7,038-8,086	7,662	100.0
Top 10 $C1\text{-}S_3$ IPHs	8,249-8,736	8,415	109.8

Table 4.27 Means of 10 traits of the top 10 C0 and C1 hybrids of each group compared with Suwan 4452 (hybrid check) from data combined over two locations in the 2005 early rainy season.

Entry	Grain yield at 15% moist.	Relat. to check	Days to 50% Ant.	Days to 50% Silk.	Height Plant	Height Ear	Lodging Stalk	Lodging Root	Foliar dis.	Grain moist.	Grain shell.
	kg ha^{-1}	%	d		cm		%	(1-5)		%	
Top 10 C0 hybrids											
AC0-S_3-228 x Ki 47	8,450	99	50	50	249	141	4	3.2	3.1	21.24	85.82
AC0-S_3-88 x Ki 47	8,317	97	51	51	247	145	1	2.1	2.9	20.56	84.30
AC0-S_3-96 x Ki 47	8,296	97	50	51	250	142	3	2.6	3.0	20.41	81.15
BC0-S_3-90 x Ki 46	8,189	95	51	52	249	142	3	2.9	2.8	20.36	83.45
AC0-S_3-159 x BC0-S_3-47	7,971	93	51	51	263	156	17	2.6	3.0	21.86	84.80
BC0-S_3-296 x Ki 46	7,727	90	51	52	239	137	1	2.0	3.0	21.54	83.60
AC0-S_3-180 x Ki 47	7,655	89	51	52	237	144	12	2.6	2.8	20.79	84.57
AC0-S_3-159 x BC0-S_3-250	7,509	88	51	51	251	144	13	2.7	3.1	20.47	81.65
AC0-S_3-72 x Ki 47	7,482	87	51	50	255	146	7	2.1	2.9	21.58	82.69
AC0-S_3-204 x BC0-S_3-47	7,184	84	50	51	255	155	7	2.6	3.1	20.35	81.54
Mean	7,878	92	51	51	249	145	7	2.5	3.0	20.91	83.36
Top 10 C0 hybrids in S_8 generation											
AC0-S_8-159 x BC0-S_8-250	8,389	98	49	50	245	132	9	1.9	3.1	19.14	86.16
AC0-S_8-72 x Ki 47	8,363	98	50	51	262	153	7	2.4	2.8	21.87	84.75
BC0-S_8-296 x Ki 46	8,126	95	52	53	236	133	1	2.2	2.6	19.39	84.14
BC0-S_8-90 x Ki 46	8,087	94	53	54	251	151	5	2.7	2.9	19.70	82.85
AC0-S_4-88 x Ki 47	7,983	93	50	51	247	145	3	2.1	2.5	21.49	83.47
AC0-S_8-228 x Ki 47	7,876	92	50	50	245	140	1	2.8	3.0	20.63	86.32
AC0-S_7-180 x Ki 47	7,851	92	52	53	240	146	4	2.1	3.1	20.21	85.64
AC0-S_8-96 x Ki 47	7,713	90	53	52	249	147	2	2.3	3.1	20.32	86.54
AC0-S_8-204 x BC0-S_8-47	7,236	84	51	53	238	134	3	1.9	3.1	20.62	83.89
AC0-S_8-159 x BC0-S_8-47	6,697	78	49	52	231	126	5	2.1	3.1	21.77	85.61
Mean	7,832	91	51	52	244	141	4	2.2	2.9	20.51	84.94
Top 10 C1 hybrids											
AC1-S_3-86-1 x Ki 47	8,878	104	50	51	244	147	1	2.4	2.8	23.25	82.75
BC1-S_3-186-16 x Ki 46	8,797	103	52	52	252	139	1	2.2	2.6	19.33	82.48
AC1-S_3-86-10 x BC1-S_3-222-20	8,736	102	52	53	259	150	2	2.5	2.9	20.58	84.38
BC1-S_3-71-22 x Ki 46	8,690	101	50	50	239	127	2	2.0	2.6	19.80	81.01
AC1-S_3-175-13 x Ki 47	8,647	101	50	51	246	151	2	2.5	2.6	22.17	85.60
AC1-S_3-180-2 x Ki 47	8,614	100	50	51	249	146	4	2.7	2.8	20.90	85.10
BC1-S_3-184-16 x Ki 46	8,605	100	52	51	243	132	2	1.9	2.9	21.12	82.97
BC1-S_3-71-1 x Ki 46	8,526	99	51	51	238	139	2	1.9	2.6	21.25	80.90
AC1-S_3-175-13 x BC1-S_3-90-7	8,478	99	51	52	257	156	4	2.7	2.6	20.60	83.49
AC1-S_2-57-12 x BC1-S_3-222-20	8,477	99	52	52	259	158	4	2.8	2.9	19.75	84.56
Mean	8,645	101	51	52	249	144	2	2.4	2.7	20.87	83.32

Table 4.27 (continued)

Entry	Grain yield at 15% moist.	Relat. to check	Days to 50% Ant.	Days to 50% Silk.	Height Plant	Height Ear	Lodging Stalk	Lodging Root	Foliar dis.	Grain moist.	Grain shell.
	kg ha^{-1}	%	d		cm		%	(1-5)		%	
Top 10 AC0 testcross hybrids											
AC0-S_3-86 x Ki 47	8,651	101	51	52	241	139	2	3.2	2.9	20.08	83.89
AC0-S_3-228 x Ki 47	8,450	99	50	50	249	141	4	3.2	3.1	21.24	85.82
AC0-S_3-88 x Ki 47	8,317	97	51	51	247	145	1	2.1	2.9	20.56	84.30
AC0-S_3-96 x Ki 47	8,296	97	50	51	250	142	3	2.6	3.0	20.41	81.15
AC0-S_3-136 x Ki 47	7,866	92	50	50	248	135	4	2.0	3.0	19.88	83.86
AC0-S_3-159 x Ki 47	7,825	91	51	51	249	149	6	1.8	2.9	21.58	85.29
AC0-S_3-180 x Ki 47	7,655	89	51	52	237	144	12	2.6	2.8	20.79	84.57
AC0-S_3-57 x Ki 47	7,596	89	51	52	246	149	3	2.1	2.8	20.52	81.56
AC0-S_3-72 x Ki 47	7,482	87	51	50	255	146	7	2.1	2.9	21.58	82.69
AC0-S_3-14 x Ki 47	7,129	83	51	53	253	145	0	1.7	3.1	19.95	82.87
Mean	7,927	92	51	51	248	144	4	2.3	2.9	20.66	83.60
Top 10 AC1 testcross hybrids											
AC1-S_3-86-1 x Ki 47	8,878	104	50	51	244	147	1	2.4	2.8	23.25	82.75
AC1-S_3-175-13 x Ki 47	8,647	101	50	51	246	151	2	2.5	2.6	22.17	85.60
AC1-S_3-180-2 x Ki 47	8,614	100	50	51	249	146	4	2.7	2.8	20.90	85.10
AC1-S_3-86-10 x Ki 47	8,430	98	51	51	254	145	2	2.5	2.8	21.15	83.76
AC1-S_2-245-17 x Ki 47	8,234	96	50	50	244	144	3	2.1	2.9	20.89	84.49
AC1-S_3-228-13 x Ki 47	8,226	96	50	51	253	150	4	2.5	3.0	18.67	86.61
AC1-S_3-88-13 x Ki 47	8,142	95	50	51	246	138	8	2.0	2.8	19.19	84.06
AC1-S_2-204-14 x Ki 47	8,044	94	49	50	245	145	9	2.6	2.8	21.14	84.97
AC1-S_2-228-3 x Ki 47	7,974	93	50	51	257	146	4	2.5	3.0	19.70	85.67
AC1-S_2-57-12 x Ki 47	7,964	93	51	51	252	150	4	2.7	2.8	21.29	85.80
Mean	8,315	97	50	51	249	146	4	2.4	2.8	20.84	84.88
Top 10 BC0 testcross hybrids											
BC0-S_3-140 x Ki 46	8,214	96	53	53	242	141	2	2.7	3.0	20.08	82.83
BC0-S_3-90 x Ki 46	8,189	95	51	52	249	142	3	2.9	2.8	20.36	83.45
BC0-S_3-184 x Ki 46	7,991	93	51	52	231	124	3	1.9	2.8	20.28	83.89
BC0-S_3-71 x Ki 46	7,878	92	52	52	233	133	1	2.2	2.5	21.38	81.51
BC0-S_3-47 x Ki 46	7,771	91	50	50	237	137	5	3.0	3.1	20.61	81.89
BC0-S_3-115 x Ki 46	7,731	90	52	53	254	147	4	2.7	2.8	20.54	77.76
BC0-S_3-296 x Ki 46	7,727	90	51	52	239	137	1	2.0	3.0	21.54	83.60
BC0-S_3-49 x Ki 46	7,330	85	51	51	232	131	2	2.0	3.0	21.18	79.59
BC0-S_3-250 x Ki 46	7,166	84	50	51	230	131	6	2.4	3.0	18.98	82.74
BC0-S_3-186 x Ki 46	6,737	79	50	52	243	132	3	2.1	2.9	19.47	83.78
Mean	7,674	89	51	52	239	135	3	2.4	2.9	20.44	82.10
Top 10 BC1 testcross hybrids											
BC1-S_3-186-16 x Ki 46	8,797	103	52	52	252	139	1	2.2	2.6	19.33	82.48
BC1-S_3-71-22 x Ki 46	8,690	101	50	50	239	127	2	2.0	2.6	19.80	81.01
BC1-S_3-184-16 x Ki 46	8,605	100	52	51	243	132	2	1.9	2.9	21.12	82.97
BC1-S_3-71-1 x Ki 46	8,526	99	51	51	238	139	2	1.9	2.6	21.25	80.90
BC1-S_3-47-9 x Ki 46	8,291	97	49	50	225	122	2	2.1	3.0	19.64	82.31
BC1-S_3-246-11 x Ki 46	8,273	96	51	51	243	143	0	2.5	2.9	19.75	81.68
BC1-S_3-90-2 x Ki 46	8,217	96	50	50	232	134	2	2.0	2.8	20.42	82.71
BC1-S_3-186-3 x Ki 46	8,213	96	50	50	247	142	4	2.5	2.6	19.41	84.29
BC1-S_3-90-7 x Ki 46	8,176	95	51	51	247	141	3	2.2	2.8	19.74	80.19
BC1-S_3-296-2 x Ki 46	8,174	95	51	51	239	139	2	1.8	2.8	21.02	84.32
Mean	8,396	98	50	51	241	136	2	2.1	2.8	20.15	82.29

Table 4.27 (continued)

Entry	Grain yield at 15% moist.	Relat. to check	Days to 50% Ant.	Days to 50% Silk.	Height Plant	Height Ear	Lodging Stalk	Lodging Root	Foliar dis.	Grain moist.	Grain shell.
	kg ha^{-1}	%	d		cm		%	(1-5)		%	
Top 10 C0 interpopulation hybrids											
AC0-S_3-159 x BC0-S_3-90	8,086	94	52	53	261	148	5	2.5	2.8	21.56	82.49
AC0-S_3-146 x BC0-S_3-184	8,051	94	51	52	249	125	3	2.3	2.8	20.70	85.75
AC0-S_3-159 x BC0-S_3-47	7,971	93	51	51	263	156	17	2.6	3.0	21.86	84.80
AC0-S_3-159 x BC0-S_3-140	7,942	93	53	54	260	155	1	2.7	2.9	21.66	86.36
AC0-S_3-159 x BC0-S_3-184	7,842	91	52	52	249	138	3	2.3	2.9	22.13	84.80
AC0-S_3-146 x BC0-S_3-296	7,555	88	51	52	247	133	3	2.2	2.8	20.57	83.52
AC0-S_3-159 x BC0-S_3-250	7,509	88	51	51	251	144	13	2.7	3.1	20.47	81.65
AC0-S_3-159 x BC0-S_3-296	7,442	87	51	52	253	142	3	1.9	2.8	22.39	83.83
AC0-S_3-204 x BC0-S_3-47	7,184	84	50	51	255	155	7	2.6	3.1	20.35	81.54
AC0-S_3-4 x BC0-S_3-250	7,038	82	52	53	247	149	5	2.6	2.9	19.59	81.49
Mean	7,662	89	51	52	253	144	6	2.4	2.9	21.13	83.62
Top 10 C1 interpopulation hybrids											
AC1-S_3-86-10 x BC1-S_3-222-20	8,736	102	52	53	259	150	2	2.5	2.9	20.58	84.38
AC1-S_3-175-13 x BC1-S_3-90-7	8,478	99	51	52	257	156	4	2.7	2.6	20.60	83.49
AC1-S_2-57-12 x BC1-S_3-222-20	8,477	99	52	52	259	158	4	2.8	2.9	19.75	84.56
AC1-S_3-180-2 x BC1-S_3-222-20	8,424	98	52	53	242	160	3	2.6	3.0	17.71	83.88
AC1-S_2-57-12 x BC1-S_3-186-16	8,421	98	52	53	263	148	1	2.6	2.9	20.58	83.05
AC1-S_2-204-14 x BC1-S_3-222-20	8,392	98	52	53	256	154	7	2.0	3.0	18.71	83.14
AC1-S_3-21-2 x BC1-S_3-71-1	8,367	98	51	51	250	145	2	2.4	2.8	20.82	82.10
AC1-S_2-204-14 x BC1-S_3-186-16	8,355	97	52	53	268	151	2	2.9	2.9	21.67	82.90
AC1-S_3-175-13 x BC1-S_3-186-16	8,255	96	53	53	267	158	5	3.1	2.8	20.40	84.00
AC1-S_3-21-9 x BC1-S_3-71-1	8,249	96	51	53	253	147	2	2.4	2.4	20.93	81.16
Mean	8,415	98	52	52	257	153	3	2.6	2.8	20.17	83.27
Hybrid checks											
NK 40	8,978	105	49	50	226	123	1	2.1	2.6	21.61	83.74
PAC 999	8,075	94	51	52	229	130	3	1.7	2.9	21.52	89.21
BIG 919	7,169	84	50	51	210	116	1	1.7	3.0	20.21	86.95
DK 888	7,819	91	53	54	245	150	5	2.5	2.8	20.63	82.15
KSX 4601	8,366	98	50	51	246	149	2	2.1	3.0	19.45	86.19
Suwan 4452 (Check)	8,576	100	51	52	235	146	6	2.5	2.6	22.19	86.00
Mean	8,164	95	51	52	232	136	3	2.1	2.8	20.93	85.71
LSD 0.05	1,349.20		2.02	2.17	10.73	8.49	6.47	0.79	0.37	1.95	3.31
LSD 0.01	1,779.50		2.67	2.86	14.16	11.20	8.54	1.04	0.48	2.57	4.37

4.2.4 Analyses for genetic variances and gca and sca effects from 100 C1 interpopulation hybrids according to Design II

Combined analyses of variance

Data of 100 C1 interpopulation hybrids (10 AC1-S_3 × 10 BC1-S_3) were analyzed according to Design II to obtain estimates of components of genetic variances and gca and sca effects.

Mean squares from combined analyses of variance for 10 traits of 100 C1 interpopulation hybrids are shown in Table 4.28. For grain yield, results were similar to C0 interpopulation hybrids which gca effects for females and males were not significant, but sca effects was significant at $P < 0.05$. For other traits, mean squares for gca for female lines were highly significant for plant height, while those of gca for male lines were highly significant for plant and ear heights and grain shelling. Mean squares for sca were highly significant for ear height, and significant for days to 50% silking. The data indicated that, in C1 interpopulation hybrids, male (BC1) was more important than female (AC1) in contributing genetic variation of gca for plant and ear heights and grain shelling. The contributions of sca effects to the expression of days to 50% silking and ear height were found to be predominant. Interaction of gca with locations was significant, while interaction of sca with locations was not significant similar to C0 interpopulation hybrids.

Estimates of components of genetic variances

Estimates of components of genetic variances of 10 traits of 100 C1 interpopulation hybrids are shown in Table 4.29. The magnitude of variance for gca for females (σ^2_f) for grain yield tended to be higher than that for males (σ^2_m). For the same trait, variance for sca (σ^2_{fm}) was 1.58 and 1.70 times greater than those variances

Table 4.28 Mean squares from analyses of variance of 10 traits of 100 C1 interpopulation hybrids from data combined over two locations in the 2005 early rainy season.

			Days to 50%		Height		Lodging		Foliar	Grain	Grain
Source of variation	**df**	**Grain yield**	**Ant.**	**Silk.**	**Plant**	**Ear**	**Stalk**	**Root**	**dis.**	**moist.**	**shell.**
		kg ha^{-1}	d		cm		%	(1-5)		%	
Locations (L)	1	89509466.45	989.10	1008.06	125677.34	81999.19	225.66	98.01	10.40	706.90	0.41
Replications/L	2	15190763.88	23.53	22.81	55.34	115.81	0.83	26.03	0.06	17.70	4.63
Varieties (V)	99	1232476.75	4.15	3.57	263.36	267.47	33.40	0.58	0.09	3.91	16.64
Females (A)	9	3157964.06	10.48	9.91	1060.32 **	452.63	70.02	1.77	0.42	16.53	44.42
Males (B)	9	2993846.36	24.08	16.00	1297.80 **	1924.36 **	114.77	2.16	0.22	14.15	90.12 **
A x B	81	822825.98 *	1.23	1.48 *	59.88	62.80 **	20.29	0.27	0.04	1.37	5.39
L x V	99	836681.06	2.22	2.32	69.90	50.24	25.00	0.44	0.06	1.71	5.90
L x A	9	1884005.17 **	4.05 **	7.32 **	173.15 **	133.69 **	31.80	1.66 **	0.27 **	4.76 **	9.38 *
L x B	9	2501409.21 **	11.39 **	9.69 **	213.16 **	157.55 **	48.07 *	0.92 **	0.05	5.46 **	16.14 **
L x (AB)	81	535341.92	1.00	0.94	42.51	29.05	21.68	0.26	0.03	0.95	4.37
Pooled error	198	453527.93	0.86	1.01	38.77	38.75	16.19	0.22	0.04	0.90	3.97

*, ** Significant at the 0.05 and 0.01 probability levels, respectively.

for gca for females and males, respectively. In terms of genetic variances, the ratio of σ^2_D/σ^2_A was 0.82 which was higher than that of C0 interpopulation hybrids (Table 4.23). The results indicated that the selection for grain yield of the testcross progenies in the MRRS program was effective for increasing variance for sca and dominance variance, which resulted in development of high-yielding interpopulation hybrids (Table 4.26). Mean grain yield of the top 10 C0 and the top 10 C1 interpopulation hybrids were high and not significantly different from mean grain yield of the top 10 C0 and the top 10 C1 testcross hybrids, respectively. The estimates of variance components for other traits showed that variance for gca for males was generally greater than that for females and both were greater than sca for all traits except for foliar diseases and grain moisture. Additive variance still had a major role for days to 50% anthesis and silking, plant and ear heights, stalk and root lodging, foliar diseases, grain moisture and grain shelling.

Table 4.29 Estimates of components of genetic variances of 10 traits of 100 C1 interpopulation hybrids from data combined over two locations in the 2005 early rainy season.

	Grain	Days to 50%		Height		Lodging		Foliar	Grain	Grain
Variance	**yield**	**Ant.**	**Silk.**	**Plant**	**Ear**	**Stalk**	**Root**	**dis.**	**moist.**	**shell.**
	kg ha^{-1}	.... d		.... cm		%	.... (1-5)		.... %	
σ^2_f	58378.45	0.23	0.21	25.01	9.75	1.24	0.04	0.01	0.38	0.98
σ^2_m	54275.51	0.57	0.36	30.95	46.54	2.36	0.05	0.00	0.32	2.12
σ^2_{fm}	92324.51	0.09	0.12	5.28	6.01	1.02	0.01	0.00	0.12	0.35
σ^2_A	112653.96	0.80	0.57	55.96	56.28	3.61	0.09	0.01	0.70	3.09
σ^2_D	92324.51	0.09	0.12	5.28	6.01	1.02	0.01	0.00	0.12	0.35
σ^2_D/σ^2_A	0.82	0.12	0.21	0.09	0.11	0.28	0.13	-0.09	0.17	0.11

Estimates of gca and sca effects

Table 4.30 presents the estimates of gca and sca effects of 10 traits of 100

C1 interpopulation hybrids. For grain yield, two C1 female lines (A4 and A7) gave significantly positive gca effects at $P < 0.01$ and $P < 0.05$, respectively. In the group of C1 male lines, two lines (B9 and B3) gave significantly positive gca effects at $P < 0.01$ and $P < 0.05$, respectively. Among 100 C1 interpopulation hybrids, four hybrids (A1 × B3, A7 × B4, A2 × B3 and A6 × B9) gave significantly positive sca effects at $P < 0.05$.

In addition, the C1 lines also gave significant gca effects for other traits. A4 line gave significantly negative gca effects for stalk lodging ($P < 0.05$; Table 4.30). A7 line gave significantly negative gca effects for days to 50% silking ($P < 0.01$), plant height ($P < 0.01$) and foliar diseases ($P < 0.01$), and significantly positive gca effects for grain shelling ($P < 0.01$).

B9 line gave significantly negative gca effects for grain moisture ($P < 0.01$; Table 4.30), and significantly positive gca effects for grain shelling ($P < 0.01$). B3 line gave significantly negative gca effects for days to 50% silking ($P < 0.05$), plant height ($P < 0.01$), stalk and root lodging ($P < 0.05$) and foliar diseases ($P < 0.01$).

From the results, the crosses of A6 × B9 or AC1-S_3-86-10 × BC1-S_3-222-20 and A7 × B4 or AC1-S_3-175-13 × BC1-S_3-90-7 were included in the top 10 C1 hybrids (Table 4.27). A6 × B9 gave higher plant height ($P < 0.01$) than the check, Suwan 4452, while A7 × B4 gave higher both plant and ear heights than the check at $P < 0.01$ and $P < 0.05$, respectively. A1 × B3 or AC1-S_3-21-2 × BC1-S_3-71-1 and A2 × B3 or AC1-S_3-21-9 × BC1-S_3-71-1 were included in the top 10 C1 interpopulation hybrids. The two hybrids had higher plant height ($P < 0.01$) and lower grain shelling percentage ($P < 0.05$ and $P < 0.01$) than the check. In addition, one female line (A7) and two male lines (B3 and B9) which were components of the four hybrids also gave significantly positive gca effects for grain yield (Table 4.30), and had high yield which were not significantly different from Ki 47 (Table 4.34).

Table 4.30 Estimates of gca and sca effects of 10 traits of 100 C1 interpopulation hybrids from data combined over two locations in the 2005 early rainy season.

Traits	Females†	Males‡										GCA effects of females
		B1	B2	B3	B4	B5	B6	B7	B8	B9	B10	
		SCA effects										
Grain yield ($kg\ ha^{-1}$)	A1	276.10	-546.97	929.61 *	-260.52	199.47	-83.85	-278.67	331.31	-141.53	-424.95	-98.01
	A2	51.90	492.94	745.13 *	-954.34 *	-353.49	-356.35	164.36	657.14	-584.47	137.20	-273.96 *
	A3	-42.55	-292.30	-32.56	-733.95 *	337.58	-77.05	42.57	4.94	375.43	417.90	-319.47 **
	A4	-71.34	-459.94	-268.60	-13.79	309.59	-16.67	137.86	358.81	-17.55	41.62	468.84 **
	A5	-342.22	490.59	209.93	341.78	53.18	-285.01	-148.43	121.43	-225.60	-215.65	145.22
	A6	535.28	447.72	-200.65	124.57	-750.29 *	167.53	560.12	-1143.55 **	728.57 *	-469.29	27.09
	A7	40.20	-354.25	-887.79 *	915.07 *	210.15	337.57	-636.01	391.00	-326.78	310.84	249.09 *
	A8	-77.83	-184.89	-269.59	251.91	-262.44	293.31	-128.86	250.61	84.02	43.76	70.27
	A9	-394.61	-214.87	-153.32	139.67	349.35	-107.50	28.03	451.06	-93.07	-4.73	164.63
	A10	25.08	621.97	-72.17	189.62	-93.09	128.02	259.04	-1422.74 **	200.98	163.30	-433.70 **
	GCA effects of males	-311.29 *	70.69	287.89 *	-119.63	-249.29 *	-166.54	-151.25	44.53	599.80 **	-4.90	
	SE§ (gca effects)	106.48										
	SE (sca effects)	336.72										
Days to 50% anthesis (d)	A1	-0.61	0.64	0.07	0.02	0.77	-1.18 *	0.39	-0.06	0.17	-0.21	-0.24
	A2	0.09	0.09	-0.23	-0.28	-0.03	0.27	0.34	-0.11	-0.13	-0.01	0.31 *
	A3	0.14	-0.11	0.07	-0.48	-0.23	0.82	-0.36	-0.06	0.17	0.04	0.51 **
	A4	-0.76	-0.01	0.67	-0.13	0.12	0.67	0.24	-0.46	-0.98 *	0.64	0.41 *
	A5	0.27	0.02	-0.56	0.14	-0.86	0.94 *	0.27	-1.18 *	0.79	0.17	-1.12 **
	A6	0.49	0.74	0.42	-0.13	-0.63	-0.33	-0.76	0.04	0.02	0.14	-0.34 *
	A7	-0.56	-0.31	-0.13	-0.43	0.32	-0.38	0.19	0.49	0.47	0.34	0.21
	A8	-0.06	-0.06	0.12	0.82	-0.43	-1.13 *	-0.06	0.49	-0.03	0.34	-0.04
	A9	0.14	-0.11	0.32	0.27	0.52	-0.18	-0.86	0.94 *	0.17	-1.21 *	-0.24
	A10	0.84	-0.91	-0.73	0.22	0.47	0.52	0.59	-0.11	-0.63	-0.26	0.56 **
	GCA effects of males	0.76 **	-1.49 **	0.08	-0.12	-0.12	0.33 *	-0.99 **	0.71 **	0.98 **	-0.14	
	SE (gca effects)	0.15										
	SE (sca effects)	0.46										

Table 4.30 (continued)

Traits	Females	Males										GCA effects of females
		B1	B2	B3	B4	B5	B6	B7	B8	B9	B10	
		SCA effects										
Days to 50% silking (d)	A1	-0.62	0.18	-0.87	0.23	0.10	-0.70	0.88	0.23	0.83	-0.25	-0.58 **
	A2	0.25	0.05	0.00	-0.15	0.23	0.18	0.00	-0.15	-0.05	-0.37	0.80 **
	A3	-0.27	0.03	-0.02	-0.67	0.20	0.40	0.23	-0.42	-0.07	0.60	0.32 *
	A4	-0.65	0.15	0.85	-0.30	0.33	0.78	0.10	-0.55	-1.20 *	0.48	0.20
	A5	-0.32	-0.02	-0.57	0.78	-1.10 *	0.60	-0.32	-0.97	0.88	1.05 *	-0.63 **
	A6	0.50	0.55	0.00	-0.65	0.23	-0.07	-0.25	-0.15	-0.55	0.38	0.30
	A7	-0.42	-0.62	0.33	0.18	-0.70	-1.00	0.33	0.43	1.03 *	0.45	-0.53 **
	A8	0.10	-0.10	0.35	0.45	-0.17	-0.97	-0.15	0.95	-0.20	-0.27	-0.05
	A9	0.38	0.18	0.63	-0.02	0.35	0.05	-1.12 *	0.73	0.08	-1.25 *	-0.33 *
	A10	1.05 *	-0.40	-0.70	0.15	0.53	0.73	0.30	-0.10	-0.75	-0.82	0.50 **
	GCA effects of males	0.67 **	-0.63 **	-0.33 *	0.07	-0.80 **	0.00	-0.58 **	0.82 **	0.97 **	-0.20	
	SE (gca effects)	0.16										
	SE (sca effects)	0.50										
Plant height (cm)	A1	1.74	0.27	4.47	2.80	-0.21	-4.63	-4.13	-1.38	0.25	0.83	-0.06
	A2	-4.36	2.74	3.27	-0.90	1.77	-3.98	0.54	4.59	-1.28	-2.40	4.29 **
	A3	-1.61	-3.13	0.00	0.78	0.90	2.10	1.70	-3.18	0.40	2.03	-0.17
	A4	1.26	2.06	0.64	0.90	-1.04	0.72	4.39	-3.09	-0.01	-5.83	4.92 **
	A5	-1.28	3.98	1.98	-2.04	-0.85	-0.29	-0.62	-3.55	1.13	1.54	-8.60 **
	A6	-2.24	2.29	2.93	-8.08 *	-2.64	2.51	2.51	-0.54	2.29	0.97	3.49 **
	A7	1.69	-6.26 *	-3.28	5.88	-7.81 *	5.70	-1.01	7.32 *	-3.18	0.95	-3.46 **
	A8	3.42	-4.80	-4.83	8.11 *	-2.45	-1.80	5.82	-1.00	-3.57	1.11	-8.04 **
	A9	1.19	1.87	-7.41 *	-4.67	7.87 *	6.32 *	-6.53 *	3.77	-1.08	-1.32	2.41 *
	A10	0.20	0.98	2.25	-2.77	4.45	-6.65 *	-2.65	-2.95	5.03	2.11	5.23 **
	GCA effects of males	-3.66 **	-9.64 **	-5.04 **	3.35 **	-0.17	0.46	-2.36 *	11.23 **	3.03 **	2.80 *	
	SE (gca effects)	0.98										
	SE (sca effects)	3.11										

Table 4.30 (continued)

Traits	Females	Males										GCA effects of females
		B1	B2	B3	B4	B5	B6	B7	B8	B9	B10	
		SCA effects										
Ear height (cm)	A1	3.89	-0.30	5.48	1.62	0.56	-7.06 *	-6.18	1.70	-1.15	1.44	-1.24
	A2	-9.78 **	-1.05	4.52	1.75	-0.76	1.15	0.33	3.65	-2.11	2.30	1.50
	A3	-0.47	2.51	0.65	-5.59	-0.85	5.36	0.46	-0.74	-3.43	2.11	0.85
	A4	3.21	-1.06	-1.77	2.41	3.36	0.54	1.29	-2.28	0.45	-6.14	3.69 **
	A5	-0.84	0.44	2.98	-3.99	1.33	-1.57	2.79	-3.29	-0.65	2.81	-6.53 **
	A6	-1.70	2.78	-1.10	-3.99	3.35	3.03	3.36	-3.19	1.92	-4.45	-4.23 **
	A7	-0.10	-1.47	-5.34	6.00	-7.78 *	1.90	-0.30	9.25 *	-2.22	0.07	3.71 **
	A8	-0.33	-1.88	-2.97	3.54	-4.81	-3.18	6.02	-1.20	6.40 *	-1.58	-1.26
	A9	0.82	-0.50	-4.66	-2.25	5.69	4.35	-8.90 *	3.90	-1.89	3.45	0.83
	A10	5.30	0.53	2.22	0.50	-0.08	-4.50	1.13	-7.79 *	2.69	0.00	2.68 *
	GCA effects of males	-1.54	-14.22 **	-1.94	5.48 **	-2.01 *	-3.79 **	-2.30 *	2.58 *	10.69 **	7.06 **	
	SE (gca effects)	0.98										
	SE (sca effects)	3.11										
Stalk lodging (%)	A1	1.53	-0.20	-2.07	5.63 *	-3.12	-1.54	0.89	0.38	-4.57 *	3.08	2.31 **
	A2	-0.81	0.36	-0.91	5.79 *	-1.99	3.43	-1.45	-0.19	0.36	-4.59 *	1.29 *
	A3	-1.13	-0.12	1.95	-2.49	-0.59	-0.49	1.98	-0.93	1.48	0.34	-1.18
	A4	2.08	0.06	0.19	-4.18 *	1.56	-0.79	-0.70	-0.73	-0.40	2.92	-1.38 *
	A5	-2.02	-2.68	0.01	1.47	-0.14	-0.67	2.80	-1.09	1.13	1.20	0.42
	A6	-0.14	-0.57	0.50	-0.95	3.47	-0.96	2.05	-0.90	-1.44	-1.05	-1.69 *
	A7	0.41	-1.52	0.56	-2.85	0.10	2.94	-0.83	3.53	-1.34	-1.00	-0.28
	A8	1.23	-0.75	-0.15	-1.46	1.35	-0.59	-0.99	2.81	-0.73	-0.72	-1.05
	A9	-1.95	7.07 **	-0.91	-0.80	0.02	-2.85	-0.84	-1.33	1.71	-0.11	0.68
	A10	0.82	-1.66	0.84	-0.16	-0.64	1.52	-2.92	-1.54	3.81	-0.07	0.87
	GCA effects of males	-0.11	-0.14	-1.70 *	4.16 **	-1.61 *	-0.73	-0.33	-0.78	1.32 *	-0.08	
	SE (gca effects)	0.64										
	SE (sca effects)	2.01										

Table 4.30 (continued)

Traits	Females	Males										GCA effects of females
		B1	B2	B3	B4	B5	B6	B7	B8	B9	B10	
		SCA effects										
Root lodging (1-5)	A1	0.04	0.04	0.38	0.16	0.16	-0.33	-0.28	-0.01	0.06	-0.23	-0.23 **
	A2	-0.53 *	0.10	0.19	-0.02	-0.02	-0.01	0.04	0.18	0.00	0.09	-0.04
	A3	-0.05	0.08	-0.09	-0.05	-0.30	-0.29	0.14	-0.10	0.23	0.44	-0.39 **
	A4	0.16	0.04	0.00	-0.34	-0.09	0.18	-0.40	-0.14	0.56 *	0.02	0.15 *
	A5	0.23	0.10	-0.06	-0.02	-0.28	-0.01	0.04	0.30	-0.25	-0.04	-0.04
	A6	-0.19	0.19	0.02	-0.06	-0.19	-0.30	0.50 *	-0.36	0.09	0.30	0.13
	A7	-0.19	-0.31	-0.10	0.06	-0.06	0.45	0.50 *	0.14	-0.29	-0.20	0.25 **
	A8	-0.07	-0.07	-0.36	0.05	-0.07	0.19	0.11	0.25	-0.05	0.04	0.26 **
	A9	0.51 *	0.01	0.10	0.14	0.26	-0.10	-0.30	0.09	-0.46	-0.25	0.05
	A10	0.09	-0.16	-0.08	0.09	0.59 *	0.23	-0.35	-0.34	0.11	-0.18	-0.15 *
	GCA effects of males	-0.35 **	0.15 *	-0.19 *	0.15 *	-0.23 **	-0.24 **	0.21 *	0.33 **	0.00	0.16 *	
	SE (gca effects)	0.07										
	SE (sca effects)	0.24										
Foliar diseases (1-5)	A1	-0.10	0.09	0.04	0.07	-0.05	0.01	-0.10	0.00	-0.05	0.10	-0.01
	A2	-0.09	-0.03	-0.20	0.09	-0.04	0.02	0.04	0.01	0.09	0.11	-0.15 **
	A3	-0.23 *	0.09	0.04	-0.05	0.07	0.01	-0.10	0.12	-0.05	0.10	-0.01
	A4	0.09	0.02	-0.03	0.01	0.01	-0.05	-0.04	-0.06	0.01	0.04	0.05
	A5	-0.01	-0.08	0.00	0.04	0.16	0.10	-0.01	0.09	-0.21 *	-0.06	-0.10 **
	A6	0.00	-0.06	0.01	-0.08	0.05	-0.01	0.00	0.10	0.05	-0.05	0.01
	A7	0.11	0.05	0.00	-0.09	0.04	-0.03	0.24 *	-0.04	0.04	-0.31 **	-0.10 **
	A8	0.09	0.02	-0.03	0.01	-0.11	0.07	0.09	-0.19	0.01	0.04	0.18 **
	A9	0.02	-0.04	0.04	-0.05	-0.05	-0.11	0.02	0.00	0.20	-0.03	-0.01
	A10	0.12	-0.06	0.14	0.05	-0.08	-0.01	-0.13	-0.03	-0.08	0.07	0.14 **
	GCA effects of males	-0.10 **	0.09 *	-0.11 **	-0.02	0.10 **	0.04	0.03	0.05	-0.02	-0.05	
	SE (gca effects)	0.03										
	SE (sca effects)	0.10										

Table 4.30 (continued)

Traits	Females	Males B1	B2	B3	B4	B5	B6	B7	B8	B9	B10	GCA effects of females
		SCA effects										
Grain moisture (%)	A1	0.53	0.81	0.26	-0.15	-0.40	-0.39	0.00	0.11	-0.20	-0.57	-0.57 **
	A2	-0.68	-1.02 *	-0.75	1.30 *	0.36	0.63	0.56	-0.35	-0.81	0.76	0.55 **
	A3	0.52	-0.13	0.76	-0.76	0.26	-0.23	-0.11	-0.81	0.53	-0.04	0.54 **
	A4	-0.13	0.34	0.81	-0.85	0.72	-0.64	0.27	-0.10	0.18	-0.61	-0.06
	A5	-0.14	-0.56	-0.15	0.23	-0.69	0.59	0.15	-0.11	0.55	0.14	-0.33 *
	A6	0.09	0.12	-1.31 *	-0.04	-0.29	0.72	0.41	0.21	0.23	-0.13	0.73 **
	A7	0.05	0.24	0.17	-0.56	-0.46	0.36	-0.50	-0.42	0.66	0.47	0.09
	A8	-0.04	0.38	0.34	0.50	-0.44	-0.56	-0.37	0.95 *	-0.58	-0.19	-1.33 **
	A9	0.56	-0.14	-1.12 *	0.08	0.54	-0.12	-0.34	1.13 *	-0.71	0.13	-0.20
	A10	-0.76	-0.05	0.98 *	0.24	0.40	-0.35	-0.06	-0.60	0.16	0.03	0.59 **
	GCA effects of males	0.58 **	-0.84 **	0.53 **	0.48 **	-0.54 **	0.54 **	-0.15	0.14	-0.98 **	0.24	
	SE (gca effects)	0.15										
	SE (sca effects)	0.47										
Grain shelling (%)	A1	1.73	-1.59	0.37	-0.36	1.17	-1.58	-0.09	0.68	-0.19	-0.14	1.52 **
	A2	2.68 *	0.40	0.82	-0.64	-2.52 *	1.41	-0.40	-1.01	-0.54	-0.21	-0.19
	A3	-1.23	-1.00	2.14 *	-0.33	0.35	-0.71	0.53	1.34	-0.20	-0.90	-1.99 **
	A4	-0.40	-0.18	0.40	0.32	-0.41	-0.79	0.57	-0.13	0.13	0.49	0.19
	A5	0.47	0.72	0.15	-1.67	0.09	-1.16	1.44	-0.44	0.78	-0.37	-0.05
	A6	-0.01	0.37	-0.78	0.64	0.12	-0.93	0.87	-0.64	0.16	0.20	0.55
	A7	0.27	-0.53	-2.44 *	1.63	1.03	-0.51	-0.75	0.15	1.56	-0.41	1.03 **
	A8	1.27	1.02	-0.52	-0.83	-0.40	1.95	-1.70	-1.38	-0.44	1.02	0.40
	A9	-1.69	1.04	0.52	0.40	1.07	0.18	-1.65	-0.03	-0.88	1.03	-0.01
	A10	-3.08 **	-0.25	-0.67	0.84	-0.52	2.14 *	1.19	1.46	-0.38	-0.73	-1.46 **
	GCA effects of males	-2.46 **	-0.28	-1.48 **	-1.19 **	-0.17	1.51 **	2.01 **	0.63 *	1.89 **	-0.47	
	SE (gca effects)	0.32										
	SE (sca effects)	1.00										

† A = AC1-S_3, ‡ B = BC1-S_3, § Standard error.

*, ** Exceeds its standard error by two and three times, respectively.

4.3 Inbred line development

Lines of each cycle were developed by using pedigree selection. The lines selected on the basis of testcross performance were evaluated for grain yield and other agronomic traits. The 11 traits collected were grain yield, 100-seed weight, days to 50% anthesis and silking, plant and ear heights, stalk and root lodging, foliar diseases, grain moisture and grain shelling. Data for other 12 traits, including seedling vigor, husk cover, plant and ear aspects, rotten ears, ears plant^{-1}, primary and secondary branches of tassel, ear lengths, ear width and kernel rows, are shown in Appendix Tables 1D-4D. For degree of leaf angle, tassel lengths and tassel width are shown in Appendix Tables 3D and 4D.

Cycle 0

4.3.1 Yield evaluation for the selected C0 lines

Combined analyses of variance

Twenty-five C0-S_5 lines each, which corresponded to the 25 top-yielders of C0-S_1 testcrosses and the lines used for recombination to form C1 populations, were selected. The 50 C0-S_5 lines (25 AC0-S_5 and 25 BC0-S_5) and six inbred lines, including Kei 0101, Kei 0102 (Ki 48), Ki 44, Ki 45, Ki 46 (check) and Ki 47 (check), were evaluated at two locations in the 2002 late rainy season using a 7 × 8 triple rectangular lattice design to assess yield potential of the C0 lines selected on the basis of testcross performance.

Mean squares from combined analyses of variance of 11 traits of the C0 lines are shown in Table 4.31. Highly significant differences ($P < 0.01$) were detected among locations for all traits except for stalk lodging and grain shelling which were not significant. Treatments were significant for all traits except stalk lodging. Grain yield was highly significant among C0 lines. The comparisons between AC0-S_5 lines vs. BC0-S_5 lines were significant for grain yield, days to 50% anthesis and silking, plant and ear heights, root lodging and grain moisture. No significant differences were detected for all traits evaluated for the C0 lines vs. checks. Interaction of treatments with locations was highly significant for grain yield, 100-seed weight and plant height.

Means of lines

Mean grain yield of the 25 AC0-S_5 lines ranged from 1,054 to 3,693 kg ha^{-1} with mean of 2,015 kg ha^{-1} or 64% of the inbred check, Ki 47 (Table 4.32). Two out of the 25 lines yielded comparatively higher than the check. The 25 BC0-S_5 lines had mean grain yield ranging from 460 to 3,280 kg ha^{-1} with mean of 1,703 kg ha^{-1} or 54% of the check. Out of the 25 lines, only one line yielded comparatively higher than the check. The results showed that the selected lines developed from population A had higher mean grain yield than the selected lines developed from population B, although the difference was not significant. These may be due to the broad genetic base of population A, Suwan1(S)C11, and the selected lines from population A were developed after 11 cycles of S_1 recurrent selection, while the selected lines from population B, KS6(S)C3, were developed after three cycles of S_1 recurrent selection. The results also corresponded to grain yield of populations per se (Table 4.5).

Each group of the selected lines was compared for other agronomic traits with the inbred check of their group (Table 4.32). Means of other traits of the 25 AC0-S_5 lines were compared with Ki 46, an inbred line developed from Suwan1(S)C10 population, while the 25 BC0-S_5 lines were compared with Ki 47, an inbred line developed from KS6(S)C3 population. The 25 AC0-S_5 lines gave more days to 50% anthesis and silking ($P < 0.01$), higher plant and ear heights ($P < 0.05$ and $P < 0.01$) and higher root lodging score ($P < 0.05$) than Ki 46. The 25 BC0-S_5 lines gave more days to 50% anthesis and silking ($P < 0.05$ and $P < 0.01$) than Ki 47. The comparisons between means of other traits of the 25 AC0-S_5 lines and the 25 BC0-S_5 lines showed no significant differences for all traits.

For the AC0-S_5 lines, 13 out of the 25 lines were components of the 30 high-yielding C0 hybrids (Table 4.32), i.e., the top 10 AC0 testcross hybrids, the top 10 BC0 testcross hybrids and the top 10 C0 interpopulation hybrids (data of the hybrids were shown in Table 4.21). The 13 lines had mean grain yield ranging from 1,054 to 3,693 kg ha^{-1} or 34 to 118% of the check, Ki 47. Grain yield of eight of the 13 lines were not significantly different from the check. Among these eight lines, AC0-S_5-159 (or A7) and AC0-S_5-96 (or A4) also gave significantly positive gca effects for grain yield (Table 4.24). For the BC0-S_5 lines, 10 out of the 25 lines were components of the 30 high-yielding C0 hybrids. The 10 lines had mean grain yield ranging from 571 to 2,969 kg ha^{-1} or 18 to 95% of the check. Grain yield of five of the 10 lines were not significantly different from the check. Among these five lines, BC0-S_5-184 (or B8), BC0-S_5-296 (or B10), BC0-S_5-90 (or B4) and BC0-S_5-250 (or B9) also gave significantly positive gca effects for grain yield (Table 4.24). Furthermore, most of the lines which were components of the top 10 C0 interpopulation hybrids were also components of the top 10 C0 testcross hybrids. The results indicated that the selected lines can be used in both testcross and interpopulation hybrids.

Most of the lines which were components of the 30 high-yielding C0 hybrids, eight of 13 AC0-S_5 lines and five of 10 BC0-S_5 lines, also had high yield. The results indicated the simultaneous development of high-yielding hybrids and their parental lines. In addition, other high-yielding lines were also obtained from C0. El-Lakany and Russell (1971), who found a positive correlation between inbred and hybrid yields, also concluded that selecting on high-yielding inbred lines will increase yield potential of the hybrids. The suggestion also corresponded to Tokatlidis (2000) who also found a positive correlation between parental lines and their single crosses for potential yield per plant. He suggested that selection within lines for yield per plant seems to be effective for hybrid potential yield per plant. Betrán et al. (2003) concluded that high-yielding inbred lines increased both grain yield of hybrid and the inbred line per se at a greater rate than observed in poor inbred lines when environmental conditions improved.

Cycle 1

4.3.2 Yield evaluation for the selected C1 and C0 lines

Combined analyses of variance

Twenty-five C1-S_4 lines each from populations A and B, which corresponded to the 25 top-yielders of C1-S_1 testcrosses and the lines used for recombination to form C2 populations, were selected. For C0 lines, 13 AC0 and 10 BC0 lines, which were components of the 30 high-yielding C0 hybrids, were reproduced in the same generation as the C1 lines. Seven AC0 and four BC0 lines included in the top 10 C0 hybrids were also produced in S_8 generation to assess their yield potential and other agronomic traits compared with S_4 lines. The 50 C1-S_4 lines (25 AC1-S_4 and 25 BC1-S_4), 23 C0-S_4 lines, 11 C0-S_8 lines and six inbred lines, including Kei 0102 (Ki 48), Kei 0303, Kei 0301, Ki 45, Ki 46 (check) and Ki 47 (check), were evaluated at two locations in the 2005 early rainy season using a 9 × 10 simple rectangular lattice design to assess yield potential of the C0 and C1 lines selected on the basis of testcross performance.

Table 4.31 Mean squares from analyses of variance of 11 traits of C0 lines from data combined over two locations in the 2002 late rainy season.

Source of variation	df	Grain yield	100-Seed weight	Days to 50% Ant.	Days to 50% Silk.	Height Plant	Height Ear	Lodging Stalk	Lodging Root	Foliar dis.	Grain moist.	Grain shell.
		kg ha^{-1}	g	d		cm		%	(1-5)		%	
Locations (L)	1	133190791.08 **	2758.99 **	484.72 **	726.92 **	49275.73 **	5967.50 **	41.76	1.29 **	6.83 **	272.47 **	27.55
Treatments (T)	55	989735.40 **	22.60 **	11.21 **	10.80 **	509.83 **	228.72 **	32.60	0.30 **	0.09 **	10.75 **	91.11 **
C0 lines	49	941795.23 **	23.19 **	11.43 **	9.21 **	422.95 **	228.05 **	34.51	0.29 **	0.10 **	9.56 **	92.43 **
AC0-S_5	24	803853.41	22.63 **	14.66 **	8.21 **	363.78 **	275.44 **	28.50	0.30 **	0.08	8.56 *	60.41 **
BC0-S_5	24	1017629.47 *	23.97 **	7.63 **	10.20 **	350.22 **	162.58 **	41.91	0.25 **	0.12 **	9.51 **	128.21 **
AC0-S_5 vs. BC0-S_5	1	2432377.11 *	18.20	25.35 **	9.51 *	3588.49 **	662.09 **	1.39	0.90 **	0.15	34.57 **	2.19
Checks	5	600083.26 *	11.82	5.73	14.16 *	263.46 **	72.95 **	16.44	0.23 *	0.04	24.48 *	78.25 **
C0 lines vs. Checks	1	5287064.19	47.15	27.66	71.77	5998.71	1040.18	19.59	1.12	0.00	0.35	90.56
T x L	55	435711.07 **	5.78 **	2.06	2.44	97.92 **	38.16	26.06	0.08	0.05	3.93	23.61
C0 lines x L	49	465845.89 **	5.88 **	2.06	2.33	91.25 *	40.07	28.15	0.09	0.05	4.05	25.49
Checks x L	5	74011.46	2.98	2.06	1.83	4.91	3.99	10.38	0.03	0.04	2.83	3.23
(C0 lines vs. Checks) x L	1	767603.00 *	15.06 *	2.05	10.79 *	889.68 **	115.16 *	1.88	0.04	0.03	3.74	33.53
Pooled error	178	171783.50	3.00	1.53	1.98	57.15	29.48	23.96	0.14	0.04	4.49	18.35
CV (%)		34.13	10.13	2.42	2.54	6.41	8.84	141.89	15.44	5.88	10.64	6.50

*, ** Significant at the 0.05 and 0.01 probability levels, respectively.

Table 4.32 Means of 11 traits of the selected 25 AC0-S_5 and 25 BC0-S_5 lines compared with the inbred checks from data combined over two locations in the 2002 late rainy season.

Entry	Grain yield at 15% moist.	Relat. to Ki 47	100-Seed weight at 15% moist.	Days to 50% Ant.	Days to 50% Silk.	Height Plant	Height Ear	Lodging Stalk	Lodging Root	Foliar dis.	Grain moist.	Grain shell.
	kg ha^{-1}	%	g	d	d	cm	cm	%	(1-5)	(1-5)	%	%
The selected 25 AC0-S_5 lines												
AC0-S_4-180	3,693	118	27.40	62	63	145	72	2	1.7	3.3	21.35	83.13
AC0-S_5-72	3,160	101	25.53	60	62	192	95	1	2.1	3.7	19.35	75.86
AC0-S_5-117	2,909	93	19.36	59	61	158	67	4	1.3	3.5	20.42	73.96
AC0-S_5-159	2,785	89	31.23	60	62	158	66	3	1.4	3.4	23.05	74.49
AC0-S_5-145	2,365	75	23.53	49	55	144	61	1	1.7	3.5	18.12	81.93
AC0-S_5-86	2,312	74	28.17	60	60	150	61	2	2.1	3.6	19.99	76.24
AC0-S_5-212	2,199	70	19.19	62	63	145	79	2	1.9	3.6	17.15	82.82
AC0-S_5-204	2,198	70	20.70	62	63	173	85	3	2.6	3.6	22.21	75.09
AC0-S_5-139	2,136	68	21.54	59	63	152	71	3	1.9	3.0	18.45	73.99
AC0-S_5-83	2,105	67	17.60	60	63	165	68	11	2.9	3.6	16.11	68.93
AC0-S_5-96	2,053	66	20.41	62	64	162	59	5	2.1	3.8	18.23	78.01
AC0-S_5-240	2,016	64	20.03	59	61	143	57	4	2.1	3.7	17.08	73.38
AC0-S_5-14	1,992	64	24.05	60	64	171	75	2	1.5	3.8	19.72	72.91
AC0-S_5-4	1,989	63	22.28	61	64	178	95	4	1.9	3.6	21.12	71.92
AC0-S_5-16	1,952	62	22.27	57	59	147	65	4	2.0	3.8	15.38	83.26
AC0-S_5-175	1,806	58	27.63	61	62	174	86	19	2.6	3.7	19.06	79.75
AC0-S_5-228	1,711	55	20.24	61	61	160	64	2	2.0	3.6	18.84	72.83
AC0-S_5-136	1,693	54	24.50	61	62	163	71	4	1.5	3.7	15.72	76.90
AC0-S_5-198	1,633	52	24.00	58	62	162	64	2	2.3	3.6	21.44	64.98
AC0-S_5-57	1,530	49	26.66	62	64	162	77	2	1.8	3.6	21.84	69.90
AC0-S_5-146	1,450	46	27.41	62	63	183	82	3	2.2	3.7	18.55	68.54
AC0-S_5-245	1,225	39	23.22	61	63	174	89	2	2.1	3.9	17.36	62.34
AC0-S_5-55	1,202	38	22.56	62	64	184	88	7	1.8	3.3	20.13	74.40
AC0-S_5-21	1,196	38	22.47	60	63	166	58	1	1.8	3.7	21.11	79.78
AC0-S_5-88	1,054	34	26.21	62	65	163	83	3	1.5	3.6	19.61	68.95
Mean	2,015	64	23.53	60	62	163	74	4	2.0	3.6	19.26	74.57

Table 4.32 (continued)

Entry	Grain yield at 15% moist.	Relat. to Ki 47	100-Seed weight at 15% moist.	Days to 50% Ant.	Days to 50% Silk.	Height Plant	Height Ear	Lodging Stalk	Lodging Root	Foliar dis.	Grain moist.	Grain shell.
	kg ha^{-1}	%	g	d	d	cm	cm	%	(1-5)	(1-5)	%	%
The selected 25 BC0-S_5 lines												
BC0-S_5-246	3,280	105	28.79	55	56	165	77	7	1.8	3.5	18.73	81.10
BC0-S_5-184	2,969	95	25.94	61	63	142	58	1	1.9	3.2	21.79	82.96
BC0-S_5-296	2,786	89	30.28	57	60	158	70	2	1.5	3.5	21.37	78.11
BC0-S_5-6	2,488	79	25.90	57	57	152	68	2	1.5	3.8	17.23	82.62
BC0-S_5-90	2,287	73	20.30	60	62	168	81	1	1.7	3.2	18.34	77.43
BC0-S_5-140	2,076	66	21.49	61	62	163	80	1	1.5	3.4	19.55	73.06
BC0-S_5-93	2,065	66	26.45	58	60	156	69	4	1.8	3.6	17.84	76.41
BC0-S_5-222	1,985	63	23.61	56	57	163	76	3	1.9	3.8	14.25	79.23
BC0-S_5-45	1,982	63	18.57	59	61	149	60	1	2.1	3.6	16.66	79.22
BC0-S_5-250	1,863	59	28.54	60	63	149	72	2	2.0	3.9	17.01	80.33
BC0-S_5-37	1,758	56	22.13	57	59	136	64	14	2.1	3.8	15.33	72.78
BC0-S_5-280	1,751	56	25.91	60	62	145	55	2	1.4	3.7	20.34	68.16
BC0-S_5-44	1,684	54	20.09	59	61	157	71	1	1.9	3.7	15.26	77.34
BC0-S_4-19	1,590	51	21.91	58	61	156	73	1	1.1	3.7	18.27	66.40
BC0-S_4-200	1,566	50	21.33	59	63	142	67	5	1.9	3.8	19.47	84.34
BC0-S_5-71	1,468	47	30.36	60	61	138	70	0	1.9	3.3	19.92	76.57
BC0-S_5-49	1,439	46	22.35	61	62	154	72	1	1.6	3.8	19.89	72.05
BC0-S_5-122	1,429	46	27.78	59	62	149	68	5	1.6	3.7	19.54	77.24
BC0-S_5-165	1,290	41	22.51	60	63	151	72	7	2.3	3.7	17.34	78.21
BC0-S_5-232	987	31	19.61	58	62	126	58	21	2.7	4.2	14.64	74.43
BC0-S_5-47	948	30	27.15	60	64	147	62	1	1.8	3.9	19.58	56.24
BC0-S_5-115	928	30	28.06	64	65	183	91	1	1.8	3.5	20.22	55.71
BC0-S_5-32	915	29	21.92	57	64	123	56	5	1.0	3.8	17.24	75.75
BC0-S_5-186	571	18	25.17	60	64	140	52	3	1.5	3.7	18.20	74.57
BC0-S_5-172	460	15	23.38	59	63	162	69	0	1.7	4.1	13.96	56.62
Mean	1,703	54	24.38	59	61	151	68	4	1.8	3.7	18.08	74.28

Table 4.32 (continued)

Entry	Grain yield at 15% moist.	Relat. to Ki 47	100-Seed weight at 15% moist.	Days to 50% Ant.	Days to 50% Silk.	Height Plant	Height Ear	Lodging Stalk	Lodging Root	Foliar dis.	Grain moist.	Grain shell.
	kg ha^{-1}	%	g	d		cm		%	(1-5)		%	
Inbred checks												
Kei 0101	1,642	52	21.68	59	63	140	66	0	1.9	3.3	24.58	71.50
Kei 0102 (Ki 48)	2,866	91	25.60	58	60	140	61	1	1.4	3.7	17.90	68.00
Ki 44	2,374	76	20.51	58	59	118	53	2	1.2	3.8	15.60	81.76
Ki 45	2,380	76	18.89	60	61	119	61	4	2.0	3.6	17.02	83.66
Ki 46 (Check)	2,970	95	23.74	56	56	141	56	0	1.3	3.7	15.41	77.93
Ki 47 (Check)	3,134	100	20.72	56	56	142	70	7	1.4	3.7	20.42	81.14
Mean	2,561	82	21.86	58	59	133	61	2	1.5	3.6	18.49	77.33
LSD 0.05	1,322.80		4.82	2.88	3.13	19.83	12.38	10.23	0.56	0.43	3.97	9.74
LSD 0.01	1,761.20		6.41	3.83	4.17	26.40	16.48	13.62	0.75	0.57	5.29	12.97

▭ = lines which were components of the 30 high-yielding C0 hybrids, i.e., the top 10 AC0 testcross hybrids, the top 10 BC0 testcross hybrids and the top 10 C0 interpopulation hybrids (Table 4.21).

Mean squares from combined analyses of variance of 11 traits of the C0 and C1 lines are shown in Table 4.33. Highly significant differences were detected among locations for all traits except for 100-seed weight and stalk lodging which were not significant. Grain yield of C0 lines and C1 lines were highly significant. The comparisons between AC0-S_4 lines vs. BC0-S_4 lines were highly significant for grain yield and plant height, and significant for ear height. The AC0-S_8 lines vs. BC0-S_8 lines was highly significant for grain yield, days to 50% silking, plant height, foliar diseases, grain moisture and grain shelling, and significant for 100-seed weight. The C0-S_4 lines vs. C0-S_8 lines was highly significant for grain yield, days to 50% anthesis and silking and plant and ear heights. For C1 lines, the AC1-S_4 lines vs. BC1-S_4 lines was highly significant for plant and ear heights, and significant for root lodging and grain shelling. The comparisons between C0 and C1 lines vs. checks showed a highly significant difference for ear height, and a significant difference for grain shelling. Interaction of treatments with locations was highly significant for grain yield and stalk lodging, and significant for foliar diseases.

Means of lines

Mean grain yield of the 25 AC1-S_4 lines ranged from 2,013 to 4,721 kg ha^{-1} with mean of 3,307 kg ha^{-1} or 87% of the inbred check, Ki 47 (Table 4.34). Eight out of the 25 lines yielded comparatively higher than the check. The 25 BC1-S_4 lines had mean grain yield ranging from 1,182 to 4,804 kg ha^{-1} with mean of 3,121 kg ha^{-1} or 82% of the check. Six out of the 25 lines yielded comparatively higher than the check. The results of the C1 lines showed that average grain yield of the selected lines developed from population A was higher than that of the selected lines developed from population B, however, the difference was not significant. The results also corresponded to grain yield of populations per se (Table 4.14).

The comparison between mean grain yield of the 25 AC1-S_4 lines and the 25 AC0-S_5 lines showed that the AC1 lines yielded higher than the AC0 lines for 23% relative to the check, Ki 47 (87% of the check in Table 4.34 vs. 64% of the check in Table 4.32). Similarly, the 25 BC1-S_4 lines yielded higher than the 25 BC0-S_5 lines for 28% relative to the check, Ki 47 (82% of the check in Table 4.34 vs. 54% of the check in Table 4.32). The results indicated the improvement for grain yield of C1 lines from both populations which were higher than C0 lines.

Means of other agronomic traits of the AC1 and BC1 lines were compared with the inbred check of their group (Table 4.34). The 25 AC1-S_4 lines had lower 100-seed weight (P < 0.05), more days to 50% anthesis and silking (P < 0.01) and higher plant and ear heights (P < 0.01) than Ki 46. The 25 BC1-S_4 lines had more days to 50% anthesis and silking (P < 0.05 and P < 0.01), higher plant and ear heights (P < 0.01) and lower grain shelling percentage (P < 0.05) than Ki 47. The comparisons between means of other traits of the 25 AC1-S_4 lines and the 25 BC1-S_4 lines showed no significant differences for all traits.

For the AC1-S_4 lines, 12 out of the 25 lines were components of the 30 high-yielding C1 hybrids (Table 4.34), i.e., the top 10 AC1 testcross hybrids, the top 10 BC1 testcross hybrids and the top 10 C1 interpopulation hybrids (data of the hybrids were shown in Table 4.27). The 12 lines had mean grain yield ranging from 2,013 to 4,540 kg ha^{-1} or 53 to 120% of the check, Ki 47. Grain yield of eight of the 12 lines were not significantly different from the check. Among these eight lines, AC1-S_4-175-13 (or A7) also gave significantly positive gca effects for grain yield (Table 4.30). For the BC1-S_4 lines, 11 out of the 25 lines were components of the 30 high-yielding

C1 hybrids. The 11 lines had mean grain yield ranging from 2,284 to 4,804 kg ha^{-1} or 60 to 127% of the check. Grain yield of nine of the 11 lines were not significantly different from the check. Among these nine lines, BC1-S_4-222-20 (or B9) and BC1-S_4-71-1 (or B3) also gave significantly positive gca effects for grain yield (Table 4.30). Moreover, the results were similar to C0 lines that most of the lines which were components of the top 10 C1 interpopulation hybrids were also components of the top 10 C1 testcross hybrids. The results indicated that the selected lines can be parental lines in both testcross and interpopulation hybrids. High-yielding lines obtained from C1 which were parental lines of the high-yielding hybrids revealed the simultaneously development of potential hybrids and their parental lines. In addition, other high-yielding lines were also obtained from C1.

The 13 AC0-S_4 lines, which were components of the 30 high-yielding C0 hybrids, had mean grain yield ranging from 1,791 to 6,021 kg ha^{-1} or 47 to 159% of the check, Ki 47 (Table 4.34). Two out of the 13 lines yielded significantly higher than the check ($P < 0.01$). For means of other traits, the 13 AC0-S_4 lines had lower 100-seed weight ($P < 0.01$), more days to 50% anthesis and silking ($P < 0.01$) and higher plant and ear heights ($P < 0.01$) than Ki 46. The 10 BC0-S_4 lines, which were components of the 30 high-yielding C0 hybrids, had mean grain yield ranging from 1,241 to 4,231 kg ha^{-1} or 33 to 112% of the check. Only one line yielded comparatively higher than the check. For means of other traits, the 10 BC0-S_4 lines had more days to 50% anthesis and silking ($P < 0.05$), higher plant and ear heights ($P < 0.01$), higher root lodging score ($P < 0.05$) and lower grain shelling percentage ($P < 0.01$) than Ki 47.

The seven AC0-S_8 lines, which were components of the top 10 C0 hybrids, had mean grain yield ranging from 1,691 to 4,087 kg ha^{-1} or 45 to 108% of the check, Ki 47 (Table 4.34). Only one line yielded comparatively higher than the check. The four BC0-S_8 lines, which were components of the top 10 C0 hybrids, had mean grain yield ranging from 651 to 3,714 kg ha^{-1} or 17 to 98% of the check. Among the C0 lines, AC0-96, AC0-180 and BC0-90 had high yield in all generations tested (S_4, S_5 and S_8), although AC0-180 was not tested in S_5 generation because its S_5 seeds was not available (Tables 4.32 and 4.34). AC0-96 (or A4) and BC0-90 (or B4) also gave significantly positive gca effects for grain yield (Table 4.24). For other traits, AC0-S_8-180 had lower 100-seed weight ($P < 0.01$) and more days to 50% anthesis and silking ($P < 0.01$) than Ki 46, but lower foliar diseases score ($P < 0.01$). AC0-S_8-96 had lower 100-seed weight ($P < 0.01$), more days to 50% anthesis and silking ($P < 0.01$), higher plant height ($P < 0.01$) and higher root lodging score ($P < 0.01$) than Ki 46, but higher grain shelling percentage ($P < 0.05$). BC0-S_8-90 had lower 100-seed weight ($P < 0.01$), more days to 50% anthesis and silking ($P < 0.01$), higher plant and ear heights ($P < 0.01$) and higher root lodging score ($P < 0.05$) than Ki 47.

Table 4.33 Mean squares from analyses of variance of 11 traits of C0 and C1 lines from data combined over two locations in the 2005 early rainy season.

Source of variation	df	Grain yield	100-Seed weight	Days to 50% Ant.	Days to 50% Silk.	Height Plant	Height Ear	Lodging Stalk	Lodging Root	Foliar dis.	Grain moist.	Grain shell.
		kg ha^{-1}	g	d	d	cm	cm	%	(1-5)	(1-5)	%	%
Locations (L)	1	10926746.04 **	0.26	817.07 **	855.87 **	42809.62 **	13936.48 **	0.26	0.87 **	2.94 **	49.72 **	77.30 **
Treatments (T)	89	2077684.13 **	22.12 **	3.07 **	4.10 **	621.51 **	222.29 **	6.20	0.29 **	0.16 **	2.31 **	90.60 **
C0 lines	33	2884008.85 **	23.30 **	2.35 **	3.47 **	582.69 **	245.87 **	13.12	0.27 **	0.19 **	0.89	136.80 **
C0-S_4	22	3011085.04 **	19.11 **	2.41 **	1.92 *	498.10 **	251.46 **	18.11	0.29 **	0.14 **	0.80	115.43 **
AC0-S_4	12	3373899.43 **	22.09 **	2.37 **	2.82 **	388.83 **	142.25 **	26.25 *	0.16 **	0.17 **	1.13	73.07 **
BC0-S_4	9	1564472.45 **	17.22 **	2.72 **	0.81	517.50 **	407.72 **	9.00	0.46 **	0.12 *	0.24	182.34 **
AC0-S_4 vs. BC0-S_4	1	11676825.71 **	0.27	0.08	1.28	1634.68 **	155.53 *	2.34	0.16	0.12	1.92	21.63
C0-S_8	10	2409912.80 **	34.31 **	1.89 *	5.03 **	677.15 **	189.93 **	2.29	0.24 **	0.30 **	1.16	193.03 **
AC0-S_8	6	1293928.55 *	35.42 **	2.82 **	4.69 **	726.93 **	183.61 **	0.90	0.36 **	0.22 **	0.28	62.59 **
BC0-S_8	3	3386885.25 **	38.38 **	0.33	2.66	367.03 *	249.58 **	2.28	0.02	0.32 **	0.78	427.24 **
AC0-S_8 vs. BC0-S_8	1	6174901.00 **	15.49 *	0.94	14.21 **	1308.78 **	48.91	10.68	0.19	0.72 **	7.61 **	273.08 **
C0-S_4 vs. C0-S_8	1	4829293.32 **	5.27	5.90 **	21.74 **	1499.07 **	682.35 **	11.54	0.08	0.04	0.05	44.66
C1 lines	49	1445784.09 **	22.82 **	3.08 **	3.67 **	506.89 **	198.56 **	1.37	0.27 **	0.13 **	2.71 *	57.40 **
AC1-S_4	24	1314843.46 **	17.93 **	2.56 **	3.50 **	343.76 **	137.93 **	1.18	0.26 **	0.14 **	3.42 **	50.46 **
BC1-S_4	24	1600988.26 **	28.52 **	3.70 **	4.00 **	605.41 **	249.82 **	1.59	0.27 **	0.13 **	2.01	65.13 **
AC1-S_4 vs. BC1-S_4	1	863459.10	3.63	0.64	0.24	2057.53 **	423.61 **	0.38	0.53 *	0.00	2.32	38.67 *
Checks	5	1076778.51	11.19 *	6.70 **	11.35 **	592.48 **	175.65	0.95	0.53	0.18 *	5.62	48.67 **
C0 and C1 lines vs. Checks	1	11064954.89	4.07	10.22	13.92	7119.84	677.98 **	4.88	0.68	0.58	0.07	435.48 *
C0 lines vs. C1 lines	1	2449327.00	21.79	1.06	0.04	1165.63	383.97	42.11	0.26	0.66	15.49	57.05
T x L	89	363969.55 **	1.75	0.69	0.97	61.78	29.57	4.56 **	0.09	0.05 *	1.28	9.69
C0 lines x L	33	390044.43 **	2.10	0.76	1.00	84.25	30.80	10.56 **	0.05	0.05 *	0.68	16.27 **
C1 lines x L	49	289057.75 *	1.59	0.72	1.03	48.06	26.39	0.94	0.10	0.05	1.56	6.42
Checks x L	5	1042091.85 **	1.49	0.13	0.58	42.43	62.39	0.95	0.12	0.03	1.91	0.99
(C0 and C1 lines vs. Checks) x L	1	86013.52	0.28	0.59	0.12	86.81	0.05	2.80	0.95 *	0.02	1.25	1.07
(C0 lines vs. C1 lines) x L	1	61520.67	0.62	0.48	0.08	64.00	10.06	4.00	0.01	0.07	4.41 *	4.63
Pooled error	142	192455.00	1.46	1.14	1.11	65.25	39.12	2.72	0.17	0.03	1.13	8.66
CV (%)		18.97	4.62	1.48	1.73	4.41	5.83	204.33	15.98	7.62	6.73	4.15

*, ** Significant at the 0.05 and 0.01 probability levels, respectively.

Table 4.34 Means of 11 traits of the selected 25 AC1-S_4 and 25 BC1-S_4 lines and the selected C0 lines compared with the inbred checks from data combined over two locations in the 2005 early rainy season.

Entry	Grain yield at 15% moist.	Relative to Ki 46	Relative to Ki 47	100-Seed weight at 15% moist.	Days to 50% Ant.	Days to 50% Silk.	Height Plant	Height Ear	Lodging Stalk	Lodging Root	Foliar dis.	Grain moist.	Grain shell.
	kg ha^{-1}	%		g	d		cm		%	(1-5)		%	
The selected 25 AC1-S_4 lines													
AC1-S_4-72-17	4,721	101	124	29.09	54	55	189	94	1	1.8	2.5	17.62	76.49
AC1-S_4-175-13	4,540	97	120	29.43	56	56	174	93	0	2.3	2.4	17.55	80.70
AC1-S_4-146-17	4,328	93	114	29.13	55	56	195	94	0	1.8	2.9	17.90	75.64
AC1-S_4-83-18	4,276	92	113	33.88	57	57	166	93	0	1.8	2.8	18.54	78.78
AC1-S_3-204-14	4,258	91	112	26.59	56	57	185	100	0	1.8	2.6	17.05	71.92
AC1-S_4-86-1	4,174	90	110	38.46	57	57	175	97	0	2.7	2.2	19.90	75.33
AC1-S_4-21-2	3,923	84	103	28.47	56	57	188	98	0	1.6	3.1	15.82	84.29
AC1-S_4-88-15	3,899	84	103	29.75	56	55	173	91	1	2.0	3.1	16.30	78.95
AC1-S_4-72-5	3,717	80	98	25.60	54	55	190	101	1	1.9	2.6	17.25	69.58
AC1-S_3-245-17	3,592	77	95	29.28	55	55	176	94	0	1.5	2.9	16.58	68.66
AC1-S_4-88-13	3,505	75	92	30.74	56	56	187	83	1	1.7	2.7	15.04	73.06
AC1-S_4-86-13	3,371	72	89	29.77	57	57	167	87	0	1.6	2.8	18.12	82.07
AC1-S_4-180-2	3,272	70	86	33.58	56	57	190	103	1	1.9	3.2	15.28	76.08
AC1-S_4-204-6	3,223	69	85	24.54	57	56	191	108	1	2.1	2.8	16.01	76.93
AC1-S_4-57-4	3,110	67	82	28.13	56	57	181	94	0	1.6	2.8	17.36	75.42
AC1-S_3-245-20	2,878	62	76	26.25	56	57	180	97	1	2.3	3.0	17.38	64.47
AC1-S_3-228-3	2,788	60	73	28.65	55	57	209	90	0	2.0	3.1	16.47	77.70
AC1-S_4-55-9	2,676	57	71	29.24	57	59	191	102	3	2.0	2.6	15.91	77.99
AC1-S_4-159-19	2,643	57	70	27.92	58	57	216	110	1	1.8	2.5	20.98	71.90
AC1-S_3-57-12	2,473	53	65	28.49	58	58	182	103	0	1.9	3.2	16.98	68.21
AC1-S_4-86-10	2,454	53	65	28.04	57	58	183	85	0	1.9	2.9	16.54	73.25
AC1-S_3-228-8	2,359	51	62	25.90	56	57	195	99	2	2.0	3.1	17.01	71.62
AC1-S_4-14-11	2,315	50	61	27.10	58	60	218	121	1	3.0	3.0	17.48	64.73
AC1-S_4-228-13	2,177	47	57	32.87	58	60	184	100	1	2.0	3.0	16.94	70.70
AC1-S_4-21-9	2,013	43	53	28.30	57	59	184	89	1	2.4	2.5	17.66	76.58
Mean	3,307	71	87	29.17	56	57	187	97	1	2.0	2.8	17.19	74.44

Table 4.34 (continued)

Entry	Grain yield at 15% moist.	Relative to Ki 46	Relative to Ki 47	100-Seed weight at 15% moist.	Days to 50% Ant.	Days to 50% Silk.	Height Plant	Height Ear	Lodging Stalk	Lodging Root	Foliar dis.	Grain moist.	Grain shell.
	kg ha^{-1}	%		g	d		cm		%	(1-5)		%	
The selected 25 BC1-S_4 lines													
BC1-S_4-186-16	4,804	103	127	29.56	56	57	213	106	1	2.0	2.9	17.77	80.07
BC1-S_4-184-16	4,508	97	119	26.63	56	56	183	94	1	1.9	2.6	18.13	82.64
BC1-S_4-172-19	4,160	89	110	31.74	56	56	177	91	1	2.4	2.8	16.03	83.94
BC1-S_4-90-12	3,993	86	105	32.48	57	57	183	91	2	2.5	2.7	16.97	80.08
BC1-S_4-32-20	3,983	86	105	28.93	54	55	148	73	0	1.3	3.0	14.94	83.64
BC1-S_4-222-20	3,895	84	103	35.18	59	60	181	104	0	1.9	2.3	16.36	75.48
BC1-S_4-186-3	3,704	80	98	27.18	54	56	184	95	0	1.8	3.1	17.24	83.14
BC1-S_4-90-7	3,520	76	93	29.54	54	55	198	108	0	2.0	3.0	15.94	73.05
BC1-S_3-280-3	3,449	74	91	25.61	56	57	180	98	0	1.9	2.8	16.88	76.28
BC1-S_4-71-1	3,310	71	87	24.37	55	55	160	84	0	1.3	2.6	18.04	79.04
BC1-S_4-184-9	3,271	70	86	25.73	56	57	145	81	1	1.8	2.7	16.23	76.73
BC1-S_4-90-2	3,171	68	84	35.44	55	56	140	75	0	1.4	2.8	17.14	75.89
BC1-S_4-184-4	3,131	67	83	25.84	57	58	175	99	0	2.4	2.5	17.21	81.77
BC1-S_4-47-9	3,111	67	82	27.63	55	57	164	78	0	2.3	3.2	16.61	77.08
BC1-S_4-186-20	3,086	66	81	27.95	57	58	183	94	0	2.1	2.7	18.52	74.69
BC1-S_4-71-22	3,057	66	81	28.15	57	56	185	84	1	2.0	2.8	16.23	77.46
BC1-S_4-115-7	2,974	64	78	30.84	57	58	191	115	2	1.7	2.8	17.68	69.93
BC1-S_4-115-6	2,955	63	78	28.01	55	56	193	99	3	1.9	2.8	18.62	73.59
BC1-S_4-246-11	2,521	54	66	27.60	57	57	195	106	1	1.7	2.7	16.73	68.55
BC1-S_4-115-9	2,354	51	62	26.96	55	56	179	88	0	1.7	3.2	15.91	70.62
BC1-S_4-32-19	2,347	50	62	26.61	58	59	176	95	1	1.5	2.6	17.26	67.33
BC1-S_4-296-2	2,284	49	60	36.64	56	57	171	85	1	1.4	2.8	16.25	80.37
BC1-S_4-296-19	1,878	40	50	32.42	57	58	168	85	0	2.3	2.9	16.02	67.88
BC1-S_4-115-19	1,389	30	37	29.18	57	58	202	109	3	1.3	3.3	18.23	64.50
BC1-S_4-37-6	1,182	25	31	19.46	59	60	167	84	1	1.5	3.4	15.11	68.42
Mean	3,121	67	82	28.79	56	57	178	93	1	1.8	2.8	16.88	75.69

Table 4.34 (continued)

Entry	Grain yield at 15% moist.	Relative to Ki 46	Ki 47	100-Seed weight at 15% moist.	Days to 50% Ant.	Silk.	Height Plant	Ear	Lodging Stalk	Root	Foliar dis.	Grain moist.	Grain shell.
	kg ha^{-1}	%		g	d		cm		%	(1-5)		%	
The 13 AC0-S$_4$ lines which were components of the 30 high-yielding C0 hybrids													
AC0-S$_4$-96	6,021	129	159	23.56	53	54	199	96	1	1.8	2.8	17.06	81.80
AC0-S$_4$-86	5,467	117	144	31.23	56	56	168	85	1	2.0	2.6	16.88	84.32
AC0-S$_4$-180	4,725	101	125	30.49	57	57	156	85	0	1.9	2.5	17.93	82.74
AC0-S$_4$-204	4,443	95	117	23.85	56	56	200	108	1	2.3	2.6	16.15	79.70
AC0-S$_4$-4	4,037	87	106	29.42	56	56	185	111	2	2.0	2.7	17.11	74.34
AC0-S$_4$-146	3,629	78	96	29.87	57	56	200	99	2	2.3	2.7	16.51	76.76
AC0-S$_4$-159	3,511	75	93	33.51	57	57	174	90	1	1.6	2.7	17.51	76.79
AC0-S$_4$-57	3,151	68	83	27.55	57	57	184	103	0	1.6	3.1	16.18	65.08
AC0-S$_4$-72	2,816	60	74	30.01	56	57	201	99	0	2.1	3.0	16.52	71.86
AC0-S$_4$-136	2,695	58	71	26.99	56	57	194	89	14	1.9	3.1	14.87	66.00
AC0-S$_4$-14	2,323	50	61	23.20	57	58	185	98	0	1.6	3.3	16.11	72.73
AC0-S$_4$-88	2,121	46	56	29.62	58	59	178	93	1	1.5	3.2	16.58	72.00
AC0-S$_4$-228	1,791	38	47	24.49	56	57	184	89	1	2.3	3.3	16.56	71.37
Mean	3,595	77	95	27.98	56	57	185	96	2	1.9	2.9	16.61	75.04
The 10 BC0-S$_4$ lines which were components of the 30 high-yielding C0 hybrids													
BC0-S$_4$-90	4,231	91	112	29.42	56	57	174	90	3	3.2	2.9	16.33	82.73
BC0-S$_4$-250	3,576	77	94	29.92	55	56	165	90	7	2.2	3.4	16.12	84.91
BC0-S$_4$-140	3,016	65	79	23.96	57	57	189	104	2	1.9	2.8	16.05	72.90
BC0-S$_4$-47	2,628	56	69	28.63	56	56	180	100	2	2.2	3.2	16.49	69.51
BC0-S$_4$-184	2,602	56	69	23.71	56	57	143	63	1	1.6	2.9	16.35	80.48
BC0-S$_4$-186	2,553	55	67	28.90	54	55	176	79	0	2.1	2.8	16.20	79.48
BC0-S$_4$-296	2,333	50	61	31.91	56	56	173	88	2	1.4	3.0	16.20	72.13
BC0-S$_4$-49	1,976	42	52	24.63	58	57	164	94	4	2.0	3.4	16.84	71.24
BC0-S$_4$-71	1,626	35	43	30.37	57	56	165	96	2	2.1	2.8	15.86	71.92
BC0-S$_4$-115	1,241	27	33	29.94	57	57	203	116	1	1.7	2.8	15.57	51.25
Mean	2,578	55	68	28.14	56	56	173	92	2	2.0	3.0	16.20	73.66

Table 4.34 (continued)

Entry	Grain yield at 15% moist.	Relative to Ki 46	Relative to Ki 47	100-Seed weight at 15% moist.	Days to 50% Ant.	Days to 50% Silk.	Height Plant	Height Ear	Lodging Stalk	Lodging Root	Foliar dis.	Grain moist.	Grain shell.
	kg ha^{-1}	%		g	d		cm		%	(1-5)		%	
The 7 AC0-S_8 lines which were components of the top 10 C0 hybrids													
AC0-S_8-180	4,087	88	108	28.05	57	59	149	81	0	2.1	2.2	16.91	80.24
AC0-S_8-96	3,662	79	96	28.49	58	57	179	86	0	2.6	3.3	16.98	84.46
AC0-S_8-72	3,361	72	89	30.93	56	57	210	103	1	2.1	2.8	16.41	73.58
AC0-S_8-204	2,967	64	78	25.43	56	56	171	87	0	2.5	2.8	16.28	75.98
AC0-S_7-228	2,685	58	71	23.42	56	56	165	86	1	2.4	2.9	17.35	73.50
AC0-S_8-159	2,433	52	64	33.43	55	56	170	77	0	1.5	2.8	16.75	72.63
AC0-S_6-88	1,691	36	45	35.20	58	60	186	99	2	1.6	3.0	17.06	67.19
Mean	2,984	64	79	29.28	57	57	176	88	1	2.1	2.9	16.82	75.37
The 4 BC0-S_8 lines which were components of the top 10 C0 hybrids													
BC0-S_8-90	3,714	80	98	21.96	57	58	179	101	3	1.9	2.7	16.12	78.55
BC0-S_7-296	1,698	36	45	31.94	57	58	159	81	1	2.0	3.3	15.61	71.22
BC0-S_8-250	1,465	31	39	26.33	58	60	154	85	3	1.9	3.6	14.71	75.82
BC0-S_7-47	651	14	17	29.92	57	60	148	74	1	1.8	3.4	15.94	46.60
Mean	1,882	40	50	27.54	57	59	160	85	2	1.9	3.2	15.60	68.04
Inbred checks													
Kei 0102 (Ki 48)	4,245	91	112	28.71	57	59	170	102	0	1.3	2.2	19.34	73.11
Kei 0303	4,202	90	111	26.37	54	54	177	90	1	1.4	2.9	16.75	85.32
Kei 0301	2,839	61	75	25.66	57	58	154	84	2	2.5	2.6	15.85	83.53
Ki 45	4,917	106	130	28.24	56	57	130	85	0	2.1	2.5	18.45	84.43
Ki 46 (Check)	4,656	100	123	32.32	53	53	156	78	0	1.7	2.9	15.48	76.36
Ki 47 (Check)	3,795	81	100	27.16	54	54	143	77	0	1.2	2.9	15.31	82.16
Mean	4,109	88	108	28.08	55	56	155	86	0	1.7	2.6	16.86	80.82
LSD 0.05	1,198.70			2.63	1.66	1.96	15.62	10.80	4.24	0.61	0.43	2.25	6.19
LSD 0.01	1,588.00			3.48	2.19	2.60	20.69	14.31	5.62	0.81	0.57	2.98	8.19

= lines which were components of the 30 high-yielding C1 hybrids, i.e., the top 10 AC1 testcross hybrids, the top 10 BC1 testcross hybrids and the top 10 C1 interpopulation hybrids (Table 4.27).

CHAPTER V

CONCLUSIONS

The MRRS program was used to improve Suwan1(S)C11 (population A) and KS6(S)C3 (population B) using respective inbred testers of Ki 47 and Ki 46 for two cycles. The population improvement showed that the selected S_1 testcrosses from AC1 and BC1 yielded higher than the selected S_1 testcrosses from AC0 and BC0 for 26.6% and 15.0%, relative to the hybrid check, Suwan 3851. After one cycle of MRRS, all C1 populations including populations per se, population crosses and population topcrosses were improved for grain yield, particularly significant improvement was found in population cross. AC1 × BC1 yielded higher than AC0 × BC0 for 10.3% ($P < 0.05$). Variety effects (v_i) and gca effects for grain yield were improved for both populations, while variety heterosis effects (h_i) was improved only for BC1. However, after two cycles of MRRS, populations per se tended to be improved for grain yield especially population A. Slight increases for grain yield of population crosses were observed. Population topcrosses were also improved for grain yield except AC2 × Ki 47. The order of populations arranged by grain yield was population topcrosses > population crosses > populations per se. AC2 and BC2 were improved for variety effects and gca effects for grain yield. Population B contributed more than population A in population cross for heterosis of grain yield. Average heterosis ($\bar{h}$) was highly significant. Also, sca effects seemed to be improved for AC2 × BC2.

The hybrid development showed significant improvement for grain yield of all

C1 hybrid groups compared with C0 hybrid groups. Mean grain yield of the top 10 C1 hybrids, the top 10 AC1 testcross hybrids, the top 10 BC1 testcross hybrids and the top 10 C1 interpopulation hybrids were higher than that of the top 10 C0 hybrids, the top 10 AC0 testcross hybrids, the top 10 BC0 testcross hybrids and the top 10 C0 interpopulation hybrids for 9.7% (P < 0.01), 4.9% (P < 0.05), 9.4% (P < 0.01) and 9.8% (P < 0.01), respectively. The top 10 C1 hybrids also had high yield which were not significantly different from the single-cross hybrid, Suwan 4452, a new hybrid which yielded higher than Suwan 3851. The top 10 hybrids from both C0 and C1 revealed that testcross hybrids had higher potential for high-yielding hybrids than interpopulation hybrids. For other agronomic traits, the top 10 AC1 testcross hybrids had only higher plant height (P < 0.05) than the check, Suwan 4452. The top 10 BC1 testcross hybrids had lower ear height (P < 0.05) and lower grain moisture (P < 0.05) than the check, but lower grain shelling percentage (P < 0.05). The top 10 C1 interpopulation hybrids had higher plant height (P < 0.01) than the check, but lower grain moisture (P < 0.05).

For grain yield of interpopulation hybrids, sca effects was important. In terms of genetic variances, ratio of σ^2_D/σ^2_A increased from 0.27 in C0 to 0.82 in C1. The selection for grain yield in the MRRS program showed that dominance variance of this trait increased while additive variance decreased. As a result, the top 10 C0 and the top 10 C1 interpopulation hybrids had mean grain yield as high as the top 10 C0 and the top 10 C1 testcross hybrids, respectively. For other traits of interpopulation hybrids, additive variance had a major role for days to 50% anthesis and silking, plant and ear heights, stalk and root lodging, foliar diseases, grain moisture and grain shelling. Among 100 C1 interpopulation hybrids, four hybrids (A1 × B3, A7 × B4, A2 × B3 and A6 × B9) gave significantly positive sca effects at $P < 0.05$. The crosses of A6 × B9 or AC1-S_3-86-10 × BC1-S_3-222-20 and A7 × B4 or AC1-S_3-175-13 × BC1-S_3-90-7 were included in the top 10 C1 hybrids. A6 × B9 had higher plant height ($P < 0.01$) than the check, Suwan 4452, while A7 × B4 had higher both plant and ear heights than the check at $P < 0.01$ and $P < 0.05$, respectively. A1 × B3 or AC1-S_3-21-2 × BC1-S_3-71-1 and A2 × B3 or AC1-S_3-21-9 × BC1-S_3-71-1 were included in the top 10 C1 interpopulation hybrids. The two hybrids had higher plant height ($P < 0.01$) and lower grain shelling percentage ($P < 0.05$ and $P < 0.01$) than the check. In addition, one female line (A7) and two male lines (B3 and B9) which were components of the four hybrids also gave significantly positive gca effects for grain yield, and had high yield which were not significantly different from Ki 47.

The line development showed the improvement for grain yield of C1 lines from both populations which were higher than C0 lines. Mean grain yield of the selected 25 lines from AC1 and BC1 were higher than that of the selected 25 lines from AC0 and BC0 for 23% and 28%, respectively, relative to the same check, Ki 47. Average grain yield of the 25 lines developed from population A tended to be higher than that of the 25 lines developed from population B for both cycles. Eight out of the 25 AC1 lines and six out of the 25 BC1 lines yielded comparatively higher than the check. However, significant increases in C1 lines were found for days to 50% anthesis and silking. Twelve out of the 25 AC1 lines and 11 out of the 25 BC1 lines were components of the 30 high-yielding C1 hybrids, i.e., the top 10 AC1 testcross hybrids, the top 10 BC1 testcross hybrids and the top 10 C1 interpopulation hybrids. Furthermore, most of the lines which were components of the top 10 interpopulation hybrids were also components of the top 10 testcross hybrids. The selected lines can be used in both testcross and interpopulation hybrids.

The MRRS program was effective in improving grain yield of both populations and lines per se and hybrid combinations (population crosses, population topcrosses to inbred testers, testcross hybrids and interpopulation hybrids). These suggested that the selection acted on both additive and nonadditive effects. High-yielding hybrids of both testcross and interpopulation hybrids and their potential parental lines can be developed simultaneously from the program.

REFERENCES

Aekatasanawan, C. (1997). Hybrid maize technology for rural development in Thailand. In **Towards the Year 2000: Technology for Rural Development; Proceedings of the International Conference** (pp. 64-81). Thailand: Chulalongkorn University.

Aekatasanawan, C. (1999). Success in genetics application to field corn breeding in Thailand. In **The 11th National Genetic Seminar** (pp. 182-187). Nakhon Ratchasima: Suranaree University of Technology. (in Thai).

Aekatasanawan, C., Aekatasanawan, C., Chulchoho, N. and Balla, C. (1998). A new single-cross hybrid corn, Suwan 3851 [Abstract]. In **The 36th Kasetsart University Annual Conference** (p. 13). Bangkok: Kasetsart University.

Aekatasanawan, C., Aekatasanawan, C., Chulchoho, N. and Balla, C. (2001a). Kasetsart inbred line of corn, Ki 46. In Inseechandrastitya Institute for Crops Research and Development (ed.). **The 10th Anniversary Inseechandrastitya Institute for Crops Research and Development** (p. 50). Bangkok: Kasetsart University. (in Thai).

Aekatasanawan, C., Chutkaew, C. and Jampatong, S. (1990). Variety diallel cross among ten open-pollinated corn varieties. In **The Proceedings of 28th Kasetsart University Annual Conference** (pp. 257-266). Bangkok: Kasetsart University. (in Thai).

Aekatasanawan, C., Chutkaew, C., Srinives, P. and Sangduen, N. (1991a). Comparison of methods for evaluating S_1 lines in two corn populations. In **The Proceedings**

of 29th Kasetsart University Annual Conference (pp. 39-48). Bangkok: Kasetsart University. (in Thai).

Aekatasanawan, C., Chutkaew, C., Srinives, P. and Sangduen, N. (1991b). Comparison of recurrent selection methods in two corn populations. In **The Proceedings of 29th Kasetsart University Annual Conference** (pp. 49-57). Bangkok: Kasetsart University. (in Thai).

Aekatasanawan, C., Chutkaew, C., Srinives, P. and Sangduen, N. (1991c). Comparison of methods for selecting lines and hybrids in two corn populations. In **The Proceedings of 29th Kasetsart University Annual Conference** (pp. 59-70). Bangkok: Kasetsart University. (in Thai).

Aekatasanawan, C., Jampatong, S., Aekatasanawan, C., Chulchoho, N. and Balla, C. (1996). Responses to S_1 recurrent selection in Suwan 1 corn variety. In **The Proceedings of 34th Kasetsart University Annual Conference** (pp. 127-134). Bangkok: Kasetsart University. (in Thai).

Aekatasanawan, C., Jampatong, S., Aekatasanawan, C., Chulchoho, N. and Balla, C. (1998). Supporting the hybrid maize breeding research in Thailand. In **Proceedings of the Seventh Asian Regional Maize Workshop** (pp. 82-91). Philippines: Los Banos.

Aekatasanawan, C., Jampatong, S., Aekatasanawan, C., Chulchoho, N. and Balla, C. (2005). Research and development of the field corn single-cross hybrid, Suwan 4452. In **The Proceedings of 43rd Kasetsart University Annual Conference** (pp. 332-343). Bangkok: Kasetsart University. (in Thai).

Aekatasanawan, C., Jampatong, S., Aekatasanawan, C., Chulchoho, N. and Balla, C. (2007). Kasetsart inbred line of corn, Ki 48. In **Proceedings of the thirty-third**

National Corn and Sorghum Research Conference (pp. 44-55). Bangkok: Kasetsart University. (in Thai).

Aekatasanawan, C., Jampatong, S., Aekatasanawan, C., Chulchoho, N., Balla, C. and Thonglarp, T. (2001b). Kasetsart inbred line of corn, Ki 47. In **Proceedings of the thirtieth National Corn and Sorghum Research Conference** (pp. 400-410). Bangkok: Kasetsart University. (in Thai).

Aekatasanawan, C., Jampatong, S. and Chutkaew, C. (1993). Research and development of corn variety, Suwan 5. In **The 32nd Kasetsart University Annual Conference** (pp. 417-427). Bangkok: Kasetsart University. Quoted in C. Aekatasanawan, S. Jampatong, C. Aekatasanawan, N. Chulchoho and C. Balla. (1998). Supporting the hybrid maize breeding research in Thailand. In **Proceedings of the Seventh Asian Regional Maize Workshop** (pp. 82-91). Philippines: Los Banos.

Aekatasanawan, C., Jampatong, S. and Chutkaew, C. (1994). Research and development of corn variety, Suwan 5. In **The 25th National Corn and Sorghum Research Conference** (pp. 1-12). Bangkok: Kasetsart University. (in Thai).

Agrawal, R.L. (1998). **Fundamentals of plant breeding and hybrid seed production.** USA: Science Publishers, Inc.

Allard, R.W. (1960). **Principles of plant breeding.** USA: John Wiley & Sons, Inc.

Betrán, F.J., Beck, D., Bänziger, M. and Edmeades, G.O. (2003). Genetic analysis of inbred and hybrid grain yield under stress and nonstress environments in tropical maize. **Crop Sci.** 43: 807-817.

Camussi, A, Landi, P. and Bertolini, M. (1988). Analysis of variety crosses to develop early base populations for reciprocal recurrent selection in maize. **Maydica** 33: 269-281.

Chutkaew, C., Jampatong, S. and Aekatasanawan, C. (1989). Research and development of corn variety, Suwan 3. In **The 27th Kasetsart University Annual Conference** (pp. 161-172). Bangkok: Kasetsart University. Quoted in C. Aekatasanawan, S. Jampatong, C. Aekatasanawan, N. Chulchoho and C. Balla. (1998). Supporting the hybrid maize breeding research in Thailand. In **Proceedings of the Seventh Asian Regional Maize Workshop** (pp. 82-91). Philippines: Los Banos.

CIMMYT. (1985). **Managing trials and reporting data for CIMMYT's international maize testing program.** Mexico, D.F.

CIMMYT. (2007). **Maize germplasm listing** [On-line]. Available: http://www.cimmyt.org/Research/Maize/GermplasmList/htm/GermplasmList.htm

Comstock, R.E. (1979). Inbred lines vs. the populations as testers in reciprocal recurrent selection. **Crop Sci.** 19: 881-886.

Comstock, R.E. and Robinson, H.F. (1948). The components of genetic variance in populations of biparental progenies and their use in estimating the average degree of dominance. **Biometrics** 4: 254-266.

Comstock, R.E. and Robinson, H.F. (1952). Estimation of average dominance of genes. In J.W. Gowen (ed.). **Heterosis** (pp. 494-516). Ames, Iowa: Iowa State University Press.

Comstock, R.E., Robinson, H.F. and Harvey, P.H. (1949). A breeding procedure designed to make maximum use of both general and specific combining ability. **Agron. J.** 41: 360-367.

Conti, S., Landi, P. and Sanguineti, M.C. (1977). Analysis of the response after two cycles of reciprocal recurrent selection on a local Italian flint variety of maize. **Maydica** 22: 101-113.

Dabholkar, A.R. (1992). **Elements of biometrical genetics.** New Delhi: Concept Publishing Company.

de la Vega, A.J. and Chapman, S.C. (2006). Multivariate analyses to display interactions between environment and general or specific combining ability in hybrid crops. **Crop Sci.** 46: 957-967.

Department of Agriculture. (n.d.). **Criteria and characteristic identification of corn varieties.** (Unpublished manuscript). (in Thai).

Doerksen, T.K., Kannenberg, L.W. and Lee, E.A. (2003). Effect of recurrent selection on combining ability in maize breeding populations. **Crop Sci.** 43: 1652-1658.

Eberhart, S.A. (1971). Regional maize diallels with US and semi-exotic varieties. **Crop Sci.** 11: 911-914.

Eberhart, S.A. and Gardner, C.O. (1966). A general model for genetic effects. **Biometrics** 22: 864-881.

Eberhart, S.A., Seme Debela and Hallauer, A.R. (1973). Reciprocal recurrent selection in the BSSS and BSCB1 maize populations and half-sib selection in BSSS. **Crop Sci.** 13: 451-456.

El-Lakany, M.A. and Russell, W.A. (1971). Relationship of maize characters with yield in testcrosses of inbreds at different plant densities. **Crop Sci.** 11: 698-701.

Eyherabide, G.H. and Hallauer, A.R. (1991a). Reciprocal full-sib recurrent selection in maize: I. Direct and indirect responses. **Crop Sci.** 31: 952-959.

Eyherabide, G.H. and Hallauer, A.R. (1991b). Reciprocal full-sib recurrent selection in maize: II. Contributions of additive, dominance, and genetic drift effects. **Crop Sci.** 31: 1442-1448.

Gardner, C.O. (1967). Simplified methods for estimating constants and computing sum of squares for diallel cross analysis. **Fitotec. Latinoam.** 4: 1-12. Quoted in

D. Mišević, A. Marić, D.E. Alexander, J. Dumanović and S. Ratković. (1989). Population cross diallel among high oil populations of maize. **Crop Sci.** 29: 613-617.

Gardner, C.O. and Eberhart, S.A. (1966). Analysis and interpretation of the variety cross diallel and related populations. **Biometrics** 22: 439-452.

Griffing, B. (1956). Concept of general and specific combining ability in relation to diallel crossing systems. **Aust. J. Biol. Sci.** 9: 463-493.

Hallauer, A.R. (1985). Compendium of recurrent selection methods and their application. **Crit. Rev. Plant Sci.** 3: 1-33.

Hallauer, A.R. and Miranda, J.B. (1988). **Quantitative genetics in maize breeding.** (2nd ed.). Ames: Iowa State University Press.

Hayman, B.I. (1954). The theory and analysis of diallel crosses. **Genetics** 39: 789-809.

Hoegemeyer, T.C. and Hallauer, A.R. (1976). Selection among and within full-sib families to develop single-crosses of maize. **Crop Sci.** 16: 76-81.

Horner, E.S., Chapman, W.H., Lundy, H.W. and Lutrick, M.C. (1972). Commercial utilization of the products of recurrent selection for specific combining ability in maize. **Crop Sci.** 12: 602-604.

Horner, E.S., Lundy, H.W., Lutrick, M.C. and Chapman, W.H. (1973). Comparison of three methods of recurrent selection in maize. **Crop Sci.** 13: 485-489.

Horner, E.S., Lundy, H.W., Lutrick, M.C. and Wallace, R.W. (1963). Relative effectiveness of recurrent selection for specific and for general combining ability in corn. **Crop Sci.** 3: 63-66.

Horner, E.S., Magloire, E. and Morera, J.A. (1989). Comparison of selection for S_2 progeny vs. testcross performance for population improvement in maize. **Crop Sci.** 29: 868-874.

Hull, F.H. (1945). Recurrent selection for specific combining ability in corn. **J. Amer. Soc. Agron.** 37: 134-145.

Inseechandrastitya Institute for Crops Research and Development. (1993). **Suwan 1: An outstanding maize variety of Thailand.** Bangkok: Kasetsart University. (in Thai).

Inseechandrastitya Institute for Crops Research and Development. (2006). **National Corn and Sorghum Research Center** [On-line]. Available: http://www.iicrd.ku.ac.th/ncsrc/ncsrc_001.htm. (in Thai).

Jampatong, S. (comp.). (1994). **Composites, synthetics and inbreds developed between 1969 and 1993 by the Corn Breeding Project Kasetsart University.** Kasetsart University: National Corn and Sorghum Research Center (Suwan Farm).

Jampatong, S., Aekatasanawan, C., Balla, C., Chulchoho, N. and Sangkaeo, K. (2001). An overview of population development for supporting hybrid maize breeding program. In **Proceedings of the Thirtieth National Corn and Sorghum Research Conference 2001** (pp. 14-25). Bangkok: Kasetsart University.

Jampatong, S., Chutkaew, C., Uppadisakul, S. and De Leon, C. (1988). Comparison of eleven methods of recurrent selection in maize. In **The Proceedings of 26th Kasetsart University Annual Conference** (pp. 211-220). Bangkok: Kasetsart University. (in Thai).

Keeratinijakal, V. and Lamkey, K.R. (1993a). Responses to reciprocal recurrent selection in BSSS and BSCB1 maize populations. **Crop Sci.** 33: 73-77.

Keeratinijakal, V. and Lamkey, K.R. (1993b). Genetic effects associated with reciprocal recurrent selection in BSSS and BSCB1 maize populations. **Crop Sci.** 33: 78-82.

Lambert, R.J. (1984). Reciprocal recurrent selection of maize in a high-yield environment. **Maydica** 29: 419-430.

Lamkey, K.R. and Hallauer, A.R. (1986). Performance of high × high, high × low, and low × low crosses of lines from the BSSS maize synthetic. **Crop Sci.** 26: 1114-1118.

Landi, P. and Frascaroli, E. (1995). Responses to a modified reciprocal recurrent selection in two maize synthetics. **Crop Sci.** 35: 791-797.

Laosuwan, P. (2007). **Statistical design and analysis** (4th ed.). Suranaree University of Technology: School of Crop Production Technology. (in Thai).

Lee, E.A., Doerksen, T.K. and Kannenberg, L.W. (2003). Genetic components of yield stability in maize breeding populations. **Crop Sci.** 43: 2018-2027.

Martin, J.M. and Hallauer, A.R. (1980). Seven cycles of reciprocal recurrent selection in BSSS and BSCB1 maize populations. **Crop Sci.** 20: 599-603.

Melani, M.D. and Carena, M.J. (2005). Alternative maize heterotic patterns for the northern Corn Belt. **Crop Sci.** 45: 2186-2194.

Menz Rademacher, M.A., Hallauer, A.R. and Russell, W.A. (1999). Comparative response of two reciprocal recurrent selection methods in BS21 and BS22 maize populations. **Crop Sci.** 39: 89-97.

Mickelson, H.R., Cordova, H., Pixley, K.V. and Bjarnason, M.S. (2001). Heterotic relationships among nine temperate and subtropical maize populations. **Crop Sci.** 41: 1012-1020.

Mišević, D. (1989). Heterotic patterns among U.S. Corn Belt, Yugoslavian, and exotic maize populations. **Maydica** 34: 353-363.

Mišević, D., Marić, A., Alexander, D.E., Dumanović, J. and Ratković, S. (1989). Population cross diallel among high oil populations of maize. **Crop Sci.** 29: 613-617.

Moreno-Gonzalez, J., Ramos-Gourcy, F. and Losada, E. (1997). Breeding potential of European flint and earliness-selected U.S. Corn Belt dent maize populations. **Crop Sci.** 37: 1475-1481.

Mungoma, C. and Pollak, L.M. (1988). Heterotic patterns among ten Corn Belt and exotic maize populations. **Crop Sci.** 28: 500-504.

Murray, L.W., Ray, I.M., Dong, H. and Segovia-Lerma, A. (2003). Clarification and reevaluation of population-based diallel analyses: Gardner and Eberhart analyses II and III revisited. **Crop Sci.** 43: 1930-1937.

Nakhon Sawan Field Crops Research Center. (2002). **Nakhon Sawan Field Crops Research Center.** (Brochure).

Narro, L., Pandey, S., Crossa, J., De León, C. and Salazar, F. (2003). Using line × tester interaction for the formation of yellow maize synthetics tolerant to acid soils. **Crop Sci.** 43: 1718-1728.

Office of Agricultural Economics. (2005). Table 7 Maize seeds: Planted area, seed quantity and rate of seeds per rai, crop year 2004/05 [Data file]. Bangkok: Center for Agricultural Information, Office of Agricultural Economics. (in Thai).

Office of Agricultural Economics. (2006a). **Table 9 Maize: Harvested area, production and yield of major countries, 2004-2006** [On-line]. Available: http://www.oae.go.th/statistic/yearbook49/section1/sec1table9.pdf

Office of Agricultural Economics. (2006b). **Table 10 Maize: Area, production, yield, farm price and farm value, 1997-2006** [On-line]. Available: http://www.oae.go.th/statistic/yearbook49/section1/sec1table10.pdf

Office of Agricultural Economics. (2006c). **Table 11 Maize: Area, production and yield by region, 2004-2006** [On-line]. Available: http://www.oae.go.th/statistic/yearbook49/section1/sec1table11.pdf

Poehlman, J.M. and Sleper, D.A. (1995). **Breeding field crops** (4th ed.). Ames: Iowa State University Press.

Rasmussen, C.C. and Hallauer, A.R. (2006). Evaluation of heterotic patterns of Iowa Stiff Stalk Synthetic and Non-Stiff Stalk Synthetic maize populations. **Maydica** 51: 177-186.

Rawlings, J.C. and Thompson, D.L. (1962). Performance level as criterion for the choice of maize testers. **Crop Sci.** 2: 217-220.

Reif, J.C., Melchinger, A.E., Xia, X.C., Warburton, M.L., Hoisington, D.A., Vasal, S.K., Srinivasan, G., Bohn, M. and Frisch, M. (2003). Genetic distance based on simple sequence repeats and heterosis in tropical maize populations. **Crop Sci.** 43: 1275-1282.

Russell, W.A., Blackburn, D.J. and Lamkey, K.R. (1992). Evaluation of a modified reciprocal recurrent selection procedure for maize improvement. **Maydica** 37: 61-67.

Russell, W.A. and Eberhart, S.A. (1975). Hybrid performance of selected maize lines from reciprocal recurrent and testcross selection programs. **Crop Sci.** 15: 1-4.

Russell, W.A., Eberhart, S.A. and Vega, U.A. (1973). Recurrent selection for specific combining ability for yield in two maize populations. **Crop Sci.** 13: 257-261.

SAS Institute. (2002). SAS software Version 9.0: SAS (r) 9.1 (TS1M3) Licensed to Kasetsart University, Site 0050317001 (SAS 9.1.3 Service Pack 3). SAS Institute Inc., Cary, NC.

Satterthwaite, F.E. (1946). An approximate distribution of estimates of variance components. **Biom. Bull.** 2: 110-114.

Shlomi, A. and Efron, Y. (1976). Variety × line cross-A suggested breeding procedure for maize in developing countries. **Theor. Appl. Genet.** 48: 255-260.

Singh, R.K. and Chaudhary, B.D. (1979). **Biometrical methods in quantitative genetic analysis** (rev. ed.). India: Kalyani Publishers.

Smith, O.S. (1986). Covariance between line per se and testcross performance. **Crop Sci.** 26: 540-543.

Snedecor, G.W. and Cochran,W.G. (1967). **Statistical methods.** USA: The Iowa State University Press.

Soengas, P., Ordás, B., Malvar, R.A., Revilla, P. and Ordás, A. (2003). Heterotic patterns among flint maize populations. **Crop Sci.** 43: 844-849.

Soengas, P., Ordás, B., Malvar, R.A., Revilla, P. and Ordás, A. (2006). Combining abilities and heterosis for adaptation in flint maize populations. **Crop Sci.** 46: 2666-2669.

Sriwatanapongse, S., Jinahyon, S. and Vasal, S.K. (1993). **Suwan-1: Maize from Thailand to the world.** Mexico, D.F.: CIMMYT.

Stojšin, D. and Kannenberg, L.W. (1994a). Genetic changes associated with different methods of recurrent selection in five maize populations: I. Directly selected traits. **Crop Sci.** 34: 1466-1472.

Stojšin, D. and Kannenberg, L.W. (1994b). Genetic changes associated with different methods of recurrent selection in five maize populations: II. Indirectly selected traits. **Crop Sci.** 34: 1473-1479.

Stoskopf, N.C., Tomes, D.T. and Christie, B.R. (1993). **Plant breeding: Theory and practice.** USA: Westview Press, Inc.

Tokatlidis, I.S. (2000). Variation within maize lines and hybrids in the absence of competition and relation between hybrid potential yield per plant with line traits. **J. Agric. Sci. (Cambridge)** 134: 391-398.

Velasco, P., Revilla, P., Malvar, R.A., Butrón, A. and Ordás, A. (2002). Resistance to corn borer in crosses between sweet and field corn populations. **J. Amer. Soc. Hort. Sci.** 127: 689-692.

Walejko, R.N. and Russell, W.A. (1977). Evaluation of recurrent selection for specific combining ability in two open-pollinated maize cultivars. **Crop Sci.** 17: 647-651.

Weyhrich, R.A., Lamkey, K.R. and Hallauer, A.R. (1998). Responses to seven methods of recurrent selection in the BS11 maize population. **Crop Sci.** 38: 308-321.

Zambezi, B.T., Horner, E.S. and Martin, F.G. (1986). Inbred lines as testers for general combining ability in maize. **Crop Sci.** 26: 908-910.

Zhang, Y., Kang, M.S. and Lamkey, K.R. (2005). DIALLEL-SAS05: A comprehensive program for Griffing's and Gardner-Eberhart analyses. **Agron. J.** 97: 1097-1106.

APPENDICES

APPENDIX A

GERMPLASMS ASSEMBLED IN THAI COMPOSITE #1

AND KS 6 MAIZE POPULATIONS

Appendix Table 1A Germplasms assembled in Thai Composite #1.†

Source	Group	Material
Caribbean Islands	Argentino	Cuba Gr.1
(16)	Argentino	Cuba 11J
	Argentino	Puerto Rico Gr.1
	Tuson	Cuba 40
	Argentino-Canilla-Criollo-Tuson	Cuba 1J
	Argentino-Canilla-Criollo-Tuson	Cuba V59
	Argentino-Canilla-Criollo-Tuson	Antigua Gr.1
	Argentino-Canilla-Criollo-Tuson	Antigua Gr.2
	Argentino-Canilla-Criollo-Tuson	Puerto Rico Gr.2
	Argentino-Canilla-Criollo-Tuson	Barbados Gr.1
	Argentino-Canilla-Criollo-Tuson	Cupurico
	Argentino-Canilla-Criollo-Tuson	Caribbean Flint Composite
	Argentino-Canilla-Criollo-Tuson	Flint Composite Amarillo
	Argentino-Canilla-Criollo-Tuson	Composite Caribbean Amarillo
	Argentino-Canilla-Criollo-Tuson	Tiquisate Golden Yellow × Caribbean Composite
	Argentino-Canilla-Criollo-Tuson	Tiquisate Golden Yellow × Guadalupe 12D-14D
Mexico and	Tuxpeño	Veracruz 163
Central America	Tuxpeño	Veracruz 181
(6)	Tuxpeño	Veracruz Gr.48
	Tuxpeño	Tamaulipas 8
	Salvadoreño	Salvadoreño Amarillo
	Argentino-Criollo	Tiquisate Golden Yellow
South America	Northern Catato	Guyana Francesca III
(5)	Cuban Yellow Dent	Bahia III BCO
	Cuban Yellow Dent	Dentado Amarillo
	Argentino-Criollo-Tuson	Nariño 330-Peru 330
	Argentino-Criollo-Tuson	DV 103
India	Caribbean-Tuxpeño-India-USA	Composite A1
(5)	Caribbean-Tuxpeño-India-USA	Multiple Cross 2
	Caribbean-Tuxpeño-India-USA	Multiple Cross 4
	Caribbean-Tuxpeño-India-USA	Synthetic A3B
	Caribbean-Tuxpeño-India-USA	Synthetic A11
Other	Tuxpeño-Caribbean-USA	Tuxpantigua
(4)	Tuxpeño-Caribbean-USA	Veracruz 181 × Antigua Gr.2
	Tuxpeño-Caribbean-USA	Usatigua
	Tuxpeño-Caribbean-USA	Florida Synthetic

Remark † From Composites, synthetics and inbreds developed between 1969 and 1993 by the Corn Breeding Project Kasetsart University (p. 36), by S. Jampatong, comp., 1994, Kasetsart University: National Corn and Sorghum Research Center (Suwan Farm).

Appendix Table 2A Germplasms assembled in KS 6.

Composite name	Developed source	Description
Caripeno DMR†	Kasetsart University Corn Breeding Project, Thailand	This composite was originated from a cross between Phil. DMR 1 and 5 to Caripeno. Caripeno is a heterogeneous population resulting from a cross between CIMMYT's synthesized Caribbean and Tuxpeño composites. Five cycles of S_1 recurrent selection for downy mildew resistance and grain yield have been completed. **Developed Year:** 1971-1973
Amarillo Dentado DMR‡	CIMMYT, Mexico	Yellow dent grain, late maturity and relatively tall plant type. High yield and good performance in lowland tropical areas of Mexico, Central America, South America and parts of Africa. It has undergone 4 cycles of improvement through IPTTs, with special attention to reduced plant height. Since 1980-81, it has undergone selection for downy mildew resistance by CIMMYT's Asian Regional Maize Program, in cooperation with Suwan Station, Kasetsart University, Thailand. **Breeding procedure/methodology** Full-Sib (FS) **Genetic material/components** Tuxpeño, Caribbean, Brazilian germplasm, ETO amarillo and 9 families from the tropical late yellow dent pool (Pool 26). **Tropical late yellow dent (TLYD); Pool 26** Relatively tall plant type, more tolerant to stunt and good yield potential. Being improved for resistance to fall armyworm. **Breeding procedure/methodology** Modified Half-Sib (MHS), alternate S_1 /S_2 and MHS **Genetic material/components** Materials from Mexico, Colombia, the Caribbean and Central America. A small fraction of US Corn Belt germplasm.
Suwan DMR Source 11†	Kasetsart University Corn Breeding Project, Thailand	This composite made from bulked pollination among CIMMYT populations. These populations are: 1. (Tuxpeño-1 x DMR) BC2-S_2 2. (Mezcla Tropical Blanca x DMR) BC1-S_2 3. (Mix.1 x Col.Gpo.1) ETO x DMR) BC1-S_2 4. (Amarillo Cristalino x DMR) BC1-S_2 5. (Amarillo Dentado x DMR) BC1-S_2 **Developed Year:** 1977
Suwan DMR Source 12 †	Kasetsart University Corn Breeding Project, Thailand	This composite made from bulked pollination among base populations from CIMMYT collaborative research program. These populations are: 1. Population 1 TLWD(C2) (stunt, streak and downy mildew selection) 2. Population 2 TLWD(C2) (downy mildew selection) 3. Population 4 TIWF(C2) (stunt, streak and downy mildew selection) 4. Population 5 TIWF(C2) (downy mildew selection) 5. Population 7 TYFD(C2) (stunt, streak and downy mildew selection) 6. Population 8 TYFD(C2) (downy mildew selection) **Developed Year:** 1977

Remark † From Composites, synthetics and inbreds developed between 1969 and 1993 by the Corn Breeding Project Kasetsart University (pp. 5, 13), by S. Jampatong, comp., 1994, Kasetsart University: National Corn and Sorghum Research Center (Suwan Farm).

‡ From Maize Germplasm Listing, by CIMMYT, Online, 2007, Available: http://www.cimmyt.org/Research/Maize/GermplasmList/htm/GermplasmList.htm

APPENDIX B

ADDITIONAL DATA FOR POPULATION IMPROVEMENT

Appendix Table 1B Mean squares from analyses of variance of six traits of the testcrosses of AC0-S_1 at Suwan Farm in the 2001 late rainy season.

Source of variation	df	Seed. vigor[1]	Husk cover	Aspect Plant	Aspect Ear	Rotten ears	Ears $Plant^{-1}$
		(1-5)				%	
Replications (Rep.)	1	3.53	0.82	0.11	1.76	170.91	137.66
Blocks/rep. (adj.)	30	0.26	0.04	0.31	0.10	9.04	64.27
Treatments (unadj.)	255	0.10	0.08 **	0.20	0.11 **	11.98	63.99 *
Treatments (adj.)	255	0.09	-	0.19 **	-	-	-
Intra-block error	225	0.07	0.04	0.11	0.07	11.01	48.24
CV (%)		19.61	14.72	12.20	11.59	200.08	7.32

*, ** Significant at the 0.05 and 0.01 probability levels, respectively.
[1] Seedling vigor.

Appendix Table 2B Mean squares from analyses of variance of six traits of the testcrosses of BC0-S_1 at Suwan Farm in the 2001 late rainy season.

Source of variation	df	Seed. vigor	Husk cover	Aspect Plant	Aspect Ear	Rotten ears	Ears $Plant^{-1}$
		(1-5)				%	
Replications (Rep.)	1	0.00	0.00	0.07	2.67	0.32	138.50
Blocks/rep. (adj.)	30	0.12	0.07	0.34	0.16	14.06	74.46
Treatments (unadj.)	255	0.08	0.09 **	0.23	0.08	12.75	70.06
Treatments (adj.)	255	-	-	0.19 **	0.07 *	-	-
Intra-block error	225	0.08	0.04	0.11	0.05	9.82	54.79
CV (%)		24.30	16.45	13.46	9.22	233.69	7.85

*, ** Significant at the 0.05 and 0.01 probability levels, respectively.

Appendix Table 3B Means of 16 traits and grain type of the 25 top-yielders of the testcrosses of AC0-S_1 at Suwan Farm in the 2001 late rainy season.

Entry	Grain yield at 15% moist.	Relat. to check	Seed. vigor	Days to 50% Ant.	Days to 50% Silk.	Height Plant	Height Ear	Lodging Stalk	Lodging Root	Foliar dis.	Husk cover	Aspect Plant	Aspect Ear	Rotten ears	Ears Plant^{-1}	Grain moist.	Grain shell.	Grain type†
	kg ha^{-1}	%	(1-5)	d		cm		%	(1-5)					%				
AC0-S_1-159 x Ki 47	10,296	200	1.9	54	53	237	137	5	2.7	2.3	1.5	2.5	2.3	0	100	26.89	80.13	OYFSF
AC0-S_1-212 x Ki 47	9,246	179	1.2	52	51	217	130	10	2.1	2.8	1.5	2.8	2.3	0	114	24.33	81.13	OYF
AC0-S_1-240 x Ki 47	9,230	179	1.2	52	52	226	125	5	1.7	2.0	1.5	1.9	1.8	0	100	27.34	77.72	OYF
AC0-S_1-96 x Ki 47	9,175	178	1.4	51	50	241	135	17	2.5	2.0	1.8	2.6	2.3	0	102	24.32	81.04	OYFSF
AC0-S_1-4 x Ki 47	8,892	173	1.3	51	51	222	129	5	2.1	2.8	2.0	3.0	2.3	0	107	23.90	78.03	OYF
AC0-S_1-146 x Ki 47	8,855	172	1.2	53	51	227	131	5	2.0	2.8	1.0	2.6	2.0	0	95	22.54	81.66	OYFSF
AC0-S_1-57 x Ki 47	8,833	171	1.1	51	50	228	134	14	2.3	2.8	1.3	2.8	2.5	2	102	25.49	80.04	OYFSF
AC0-S_1-83 x Ki 47	8,774	170	1.1	52	51	226	133	7	2.3	2.5	1.5	2.5	2.3	0	100	24.27	80.33	OYFSF
AC0-S_1-204 x Ki 47	8,719	169	1.5	50	49	235	128	7	2.1	2.5	1.5	2.6	2.3	0	98	24.12	79.57	OYFSF
AC0-S_1-145 x Ki 47	8,684	168	1.2	53	54	228	125	7	2.3	3.0	1.5	2.8	2.5	0	100	27.72	80.04	OYF
AC0-S_1-136 x Ki 47	8,644	168	1.3	52	53	226	123	14	2.0	2.3	1.3	2.3	2.3	2	107	23.34	81.34	OYF
AC0-S_1-175 x Ki 47	8,619	167	1.7	51	50	230	134	10	2.3	2.5	1.5	2.5	2.0	3	93	26.89	81.73	OYFSF
AC0-S_1-86 x Ki 47	8,609	167	1.5	53	54	225	122	0	2.0	2.5	1.5	2.5	1.8	0	97	26.13	78.30	OYFSF
AC0-S_1-72 x Ki 47	8,557	166	1.6	53	53	238	134	7	2.3	2.3	1.8	2.6	2.3	0	95	26.36	79.54	OYFSF
AC0-S_1-16 x Ki 47	8,546	166	1.3	52	53	234	138	0	2.3	3.0	1.8	3.1	2.5	0	100	23.50	80.23	OYF
AC0-S_1-228 x Ki 47	8,517	165	1.4	53	51	238	137	10	2.5	2.5	1.5	2.5	2.3	0	108	27.02	82.32	OYFSF
AC0-S_1-14 x Ki 47	8,495	165	1.3	53	53	248	142	17	2.0	2.8	1.8	2.7	1.8	0	100	27.25	79.34	OYF
AC0-S_1-55 x Ki 47	8,412	163	1.3	54	54	243	139	10	2.2	2.8	1.0	2.7	2.3	7	105	24.74	79.57	OYFSF
AC0-S_1-88 x Ki 47	8,394	163	1.2	53	51	223	131	5	1.8	2.8	1.0	2.8	1.8	0	102	25.83	79.62	OYFSF
AC0-S_1-245 x Ki 47	8,383	163	1.3	52	51	231	137	3	2.0	2.8	1.5	2.8	2.3	0	98	27.03	79.46	OYFSF
AC0-S_1-180 x Ki 47	8,365	162	1.4	54	54	223	128	5	2.0	2.5	1.8	2.5	2.3	4	107	26.67	78.26	OYFSF
AC0-S_1-139 x Ki 47	8,335	162	1.8	54	53	226	127	10	1.6	2.5	1.5	2.5	1.8	0	100	23.89	81.19	OYF
AC0-S_1-21 x Ki 47	8,335	162	1.2	51	50	241	130	18	2.2	2.5	1.0	2.7	2.0	0	98	25.18	81.09	OYFSF
AC0-S_1-117 x Ki 47	8,331	162	1.4	52	53	226	134	2	1.8	2.8	1.8	2.8	2.5	5	102	28.09	80.00	OYFSF
AC0-S_1-198 x Ki 47	8,323	161	1.4	52	53	226	121	14	2.6	2.5	1.5	2.6	1.8	0	98	27.61	77.15	OYFSF
BIG 919	4,503	87	1.4	54	54	202	106	71	2.9	3.5	1.8	3.7	3.3	7	98	21.90	78.46	OYFSF
BIG 949	6,157	119	1.5	53	53	206	112	2	2.1	1.5	1.0	1.6	2.5	0	83	29.09	80.43	OYFSF
PIONEER 30A33	7,570	147	1.4	49	49	203	115	50	1.5	2.5	1.5	2.4	2.8	0	100	22.30	83.12	OYFSF
KSX 4156	6,994	136	1.9	52	51	231	126	19	2.2	3.0	1.0	3.0	2.0	3	98	24.30	81.12	OYFSF
Suwan 3853	6,799	132	1.3	52	50	209	125	3	1.8	3.5	2.0	3.5	2.5	3	98	25.34	81.99	OY^SF
Suwan 3851 (Check)	5,154	100	2.0	54	53	209	126	21	3.4	2.5	1.5	3.1	2.8	11	86	28.09	79.44	OY^FSF
Mean	8,218	159	1.4	52	52	227	129	12	2.2	2.6	1.5	2.7	2.2	2	100	25.53	80.11	
LSD 0.05	1,536.12		0.55	2.90	3.35	18.14	13.92	25.18	0.89	0.56	0.42	0.67	0.53	6.54	13.68	3.74	2.80	
LSD 0.01	2,024.36		0.73	3.83	4.42	23.92	18.35	33.19	1.18	0.74	0.55	0.88	0.70	8.61	18.02	4.92	3.70	

† OYF = orange-yellow flint, OYFSF = OYF-SF (orange-yellow flint and semi-flint), OY^SF = OŶSF (orange-yellow semi-flint with yellow cap), OY^FSF = OŶF-SF (orange-yellow flint and semi-flint with yellow cap).

Appendix Table 4B Means of 16 traits and grain type of the 25 top-yielders of the testcrosses of BC0-S_1 at Suwan Farm in the 2001 late rainy season.

Entry	Grain yield at 15% moist.	Relat. to check	Seed. vigor	Days to 50% Ant.	Days to 50% Silk.	Height Plant	Height Ear	Lodging Stalk	Lodging Root	Foliar dis.	Husk cover	Aspect Plant	Aspect Ear	Rotten ears	Ears Plant^{-1}	Grain moist.	Grain shell.	Grain type
	kg ha^{-1}	%	(1-5)	d		cm		%	(1-5)					%				
BC0-S_1-184 x Ki 46	9,461	124	1.0	52	49	210	103	0	1.5	2.1	1.5	2.1	2.4	0	110	26.90	80.70	OYF
BC0-S_1-49 x Ki 46	9,402	123	1.3	52	51	200	107	0	1.7	2.0	1.5	2.0	2.4	0	100	26.88	77.89	OYFSF
BC0-S_1-296 x Ki 46	9,299	121	1.3	52	52	209	124	1	2.2	2.2	1.0	2.5	2.3	0	102	28.72	79.54	OYF
BC0-S_1-122 x Ki 46	9,198	120	1.0	52	53	211	115	1	2.1	2.3	1.0	2.3	2.1	3	100	26.44	79.96	OYF
BC0-S_1-44 x Ki 46	9,079	119	1.0	53	51	213	114	-1	2.0	2.7	1.5	2.6	2.6	0	100	25.49	77.95	OYFSF
BC0-S_1-250 x Ki 46	9,044	118	1.0	53	52	208	113	1	2.1	2.1	1.5	2.3	2.5	5	100	27.12	79.03	OYF
BC0-S_1-140 x Ki 46	8,988	117	1.0	54	53	212	117	0	2.3	2.2	1.3	2.2	2.2	2	98	25.88	78.48	OYF
BC0-S_1-47 x Ki 46	8,978	117	1.3	53	52	213	125	7	1.9	2.3	1.5	2.2	2.3	0	100	26.66	76.94	OYFSF
BC0-S_1-93 x Ki 46	8,922	117	1.3	53	53	198	105	5	1.9	2.3	1.3	2.2	2.5	0	93	25.97	80.79	OYF
BC0-S_1-90 x Ki 46	8,916	116	1.0	53	50	221	128	15	2.3	2.2	1.0	2.3	2.3	0	98	27.88	81.57	OYFSF
BC0-S_1-45 x Ki 46	8,893	116	1.0	52	52	216	119	19	3.0	2.5	1.5	2.9	2.5	0	102	26.48	78.79	OYF
BC0-S_1-246 x Ki 46	8,892	116	1.0	53	51	208	113	1	2.0	2.2	1.0	2.4	2.5	2	103	23.72	78.35	OYFSF
BC0-S_1-32 x Ki 46	8,853	116	1.3	51	51	200	111	2	2.1	2.4	1.5	2.4	2.3	0	100	24.25	76.72	OYF
BC0-S_1-232 x Ki 46	8,763	114	1.5	53	51	216	123	9	1.6	2.4	1.5	2.3	2.2	0	90	27.40	81.51	OYF
BC0-S_1-222 x Ki 46	8,742	114	1.5	53	53	213	120	6	2.3	2.3	1.3	2.3	2.2	0	102	23.75	77.14	OYF
BC0-S_1-71 x Ki 46	8,737	114	1.0	54	52	210	112	0	2.0	2.0	1.3	2.0	2.4	0	95	26.76	79.42	OYFSF
BC0-S_1-19 x Ki 46	8,716	114	1.0	53	52	210	115	5	2.1	2.3	1.3	2.3	2.3	0	98	25.52	75.87	OYFSF
BC0-S_1-186 x Ki 46	8,669	113	1.3	52	53	210	110	-1	2.4	2.0	1.3	2.5	2.3	0	95	27.21	78.94	OYF
BC0-S_1-200 x Ki 46	8,641	113	1.3	53	53	208	117	15	2.3	1.9	1.0	2.2	2.5	3	98	26.91	80.08	OYF
BC0-S_1-37 x Ki 46	8,629	113	1.3	52	52	210	112	8	2.0	2.8	1.3	2.8	2.2	0	98	25.12	78.08	OYFSF
BC0-S_1-172 x Ki 46	8,622	113	1.8	54	54	207	118	4	2.0	2.4	1.5	2.5	1.9	0	93	23.43	78.10	OYF
BC0-S_1-280 x Ki 46	8,537	112	1.0	52	51	212	118	3	1.6	2.0	1.0	2.1	2.6	0	102	26.99	74.94	OYF
BC0-S_1-115 x Ki 46	8,504	111	1.0	53	55	220	124	8	1.8	2.2	1.0	2.3	2.1	0	95	27.14	77.51	OYF
BC0-S_1-6 x Ki 46	8,502	111	1.0	52	51	209	116	10	2.3	2.5	1.5	2.8	2.5	0	93	24.98	92.69	OYF
BC0-S_1-165 x Ki 46	8,498	111	1.0	54	52	213	121	9	2.3	2.4	1.0	2.5	2.5	0	98	25.94	78.67	OYFSF
BIG 919	5,557	73	1.0	52	52	184	101	16	2.5	3.2	1.5	3.2	2.5	0	98	24.23	79.61	OYSF
BIG 949	7,897	103	1.0	55	54	203	109	21	2.1	1.8	1.5	1.9	2.3	2	100	29.14	81.19	OYFSF
PIONEER 30A33	7,766	101	1.5	52	51	206	113	36	2.0	2.9	1.5	2.8	2.3	3	100	24.17	82.78	OY^FSF
KSX 4156	7,130	93	1.3	53	53	210	117	3	2.1	2.6	1.0	2.6	1.7	0	95	25.18	82.17	OY^SF
Suwan 3853	6,547	86	1.8	52	53	213	128	1	2.6	3.6	1.8	3.4	2.5	0	93	25.01	80.70	OYFSF
Suwan 3851 (Check)	7,655	100	1.3	51	50	205	118	10	2.5	2.4	1.8	2.5	2.5	0	95	27.79	81.09	OY^F
Mean	8,517	111	1.2	53	52	209	116	7	2.1	2.4	1.3	2.4	2.3	1	98	26.10	79.59	
LSD 0.05	1,586.84		0.55	1.88	2.55	14.39	11.45	16.76	0.80	0.58	0.41	0.68	0.45	6.17	14.58	3.56	5.72	
LSD 0.01	2,091.98		0.72	2.48	3.36	18.97	15.10	22.09	1.06	0.76	0.54	0.89	0.60	8.13	19.21	4.70	7.54	

Appendix Table 5B Mean squares from analyses of variance of six traits of 14 populations and two population checks from data combined over two locations in the 2002 late rainy season.

Source of variation	df	Seed. vigor	Husk cover	Aspect Plant	Aspect Ear	Rotten ears	Ears Plant^{-1}
		(1-5)				%	
Locations (L)	1	1.22 **	0.03	14.78 **	2.39 **	622.57 **	3031.85 **
Replications within location (R/L)	6	0.14	0.01	0.25	0.35	17.17	194.17
Treatments (T)	15	0.07	0.01	0.10 *	0.51 **	24.75	94.33 *
Populations per se	3	0.02	0.03	0.19 *	0.05	27.90	44.01
C0 populations per se	1	0.06	0.02	0.14 *	0.02	21.02	36.65
C1 populations per se	1	0.00	0.06	0.14 *	0.02	10.86	63.21
C0 vs. C1 populations per se	1	0.00	0.01	0.28 *	0.13 *	51.81	32.18
Population crosses	5	0.03	0.01	0.10 **	0.18	13.13	44.85
Population topcrosses	3	0.05	0.00	0.09	0.36	4.50	35.14
C0 population topcrosses	1	0.06	0.00	0.14	0.14	6.11	9.95
C1 population topcrosses	1	0.02	0.00	0.02	0.56	5.79	60.13
C0 vs. C1 population topcrosses	1	0.07	0.00	0.13	0.38	1.60	35.34
Checks	1	0.14	0.00	0.14	0.39	74.22	118.59
All populations vs. Checks	1	0.00	0.00	0.01	0.91	25.53	277.03
per se vs. Crosses and topcrosses	1	0.01	0.04	0.00	1.65	61.13	326.70
Population crosses vs. Topcrosses	1	0.57	0.00	0.02	2.48	47.59	230.91
T x L	15	0.07	0.01	0.03	0.10	10.87	32.01
Populations per se x L	3	0.05	0.03 **	0.01	0.01	11.85	22.39
Population crosses x L	5	0.03	0.01	0.01	0.14	9.86	10.27
Population topcrosses x L	3	0.15 *	0.00	0.05	0.13	2.00	40.23
Checks x L	1	0.02	0.00	0.02	0.14	8.93	34.39
(All populations vs. Checks) x L	1	0.00	0.00	0.00	0.01	6.14	98.91
(per se vs. Crosses and topcrosses) x L	1	0.15	0.04 *	0.20 *	0.07	10.34	20.23
(Population crosses vs. Topcrosses) x L	1	0.04	0.00	0.05	0.09	46.75 *	87.43
Pooled error	90	0.04	0.01	0.05	0.08	10.55	33.92
CV (%)		16.82	8.00	6.62	12.23	106.78	6.35

*, ** Significant at the 0.05 and 0.01 probability levels, respectively.

Appendix Table 6B Means of 16 traits and grain type of 14 populations and two population checks from data combined over two locations in the 2002 late rainy season.

Entry	Grain yield at 15% moist.	Relat. to check	Seed. vigor	Days to 50% Ant.	Days to 50% Silk.	Height Plant	Height Ear	Lodging Stalk	Lodging Root	Foliar dis.	Husk cover	Aspect Plant	Aspect Ear	Rotten ears	Ears Plant^{-1}	Grain moist.	Grain shell.	Grain type
	kg ha^{-1}	%	(1-5)	d		cm		%		(1-5)				%				
AC1	5,176	110	1.2	58	58	222	109	2	2.1	3.3	1.1	3.3	2.4	2	93	24.97	78.26	OYF
BC1	5,124	109	1.2	57	58	219	107	1	1.9	3.1	1.0	3.1	2.5	4	89	23.80	78.66	OYFSF
AC0	4,918	105	1.1	57	58	216	109	1	2.2	3.3	1.1	3.3	2.6	4	90	24.37	77.44	OYF
BC0	4,792	102	1.3	56	56	207	103	4	1.8	3.4	1.0	3.4	2.6	6	87	22.73	77.67	OYFSF
AC1 x BC1	5,860	125	1.1	56	57	223	111	3	1.9	3.3	1.1	3.3	2.2	4	93	24.69	78.32	OYFSF
AC0 x BC1	5,817	124	1.1	56	57	220	112	3	2.0	3.2	1.0	3.2	2.3	2	95	23.78	78.73	OYFSF
AC1 x BC0	5,399	115	1.1	56	57	217	111	1	1.9	3.1	1.0	3.1	2.4	3	91	24.48	77.83	OYFSF
AC0 x BC0	5,313	113	1.0	55	57	216	105	3	1.9	3.4	1.0	3.4	2.5	2	92	24.69	77.98	OYFSF
AC1 x AC0	4,905	105	1.1	57	58	217	107	2	2.0	3.3	1.0	3.3	2.6	5	93	24.90	77.36	OYF
BC1 x BC0	4,902	104	1.2	56	57	212	102	1	1.6	3.2	1.0	3.2	2.5	3	88	23.58	79.04	OYFSF
AC1 x Ki 47	6,621	141	1.2	56	56	217	112	1	1.8	3.2	1.0	3.2	1.8	2	98	25.64	80.08	OYF
AC0 x Ki 47	6,193	132	1.3	55	56	220	118	1	1.8	3.4	1.0	3.4	2.1	2	95	24.87	79.29	OYF
BC1 x Ki 46	6,017	128	1.3	56	57	210	102	2	1.6	3.3	1.0	3.3	2.1	1	95	25.04	78.21	OYF
BC0 x Ki 46	5,624	120	1.4	56	57	210	104	0	1.6	3.3	1.0	3.3	2.3	1	94	24.35	77.59	OYF
Suwan3(S)C4	4,208	90	1.3	56	57	210	98	2	1.9	3.4	1.0	3.4	2.8	6	85	23.45	77.10	OYF
Suwan5(S)C3 (Check)	4,691	100	1.1	57	57	216	100	3	1.9	3.2	1.0	3.2	2.4	2	91	23.91	78.65	OYF
Mean	5,348	114	1.2	56	57	216	107	2	1.9	3.3	1.0	3.3	2.4	3	92	24.33	78.26	
LSD 0.05	484.20		0.20	0.83	0.85	7.48	7.02	2.38	0.36	0.21	0.08	0.21	0.29	3.23	5.79	1.21	1.23	
LSD 0.01	641.37		0.26	1.10	1.12	9.91	9.30	3.15	0.48	0.28	0.11	0.28	0.38	4.27	7.66	1.60	1.63	

Appendix Table 7B Mean squares from Gardner-Eberhart Analysis II and Analysis III of six traits from four populations per se and their six diallel crosses, from data combined over two locations in the 2002 late rainy season.

Source of variation	df	Seed. vigor	Husk cover	Aspect Plant	Aspect Ear	Rotten ears	Ears Plant^{-1}
		(1-5)				%	
Gardner-Eberhart Analysis II							
Varieties	3	0.03	0.02	0.16	0.16	7.61	79.82
Heterosis	6	0.04	0.01	0.10	0.08	23.02	35.06
Average heterosis	1	0.17	0.03	0.00	0.30	19.42 *	109.99 *
Variety heterosis	3	0.00	0.01	0.06 *	0.08	37.04	25.49
Specific heterosis	2	0.06	0.01	0.20 *	0.19	7.70	20.19
Varieties x L	3	0.05	0.02	0.02	0.02	4.79	13.99
Heterosis x L	6	0.04	0.01	0.03	0.13	11.75 *	8.38
Average heterosis x L	1	0.08	0.03	0.25 *	0.13	0.05	0.15
Variety heterosis x L	3	0.02	0.01	0.00	0.05	21.97 **	21.55
Specific heterosis x L	2	0.06	0.01	0.01	0.27 *	2.28	5.95
Gardner-Eberhart Analysis III							
Varieties	3	0.02	0.03	0.19 *	0.05	27.90	44.01
Varieties vs. Crosses	1	0.17	0.03	0.00	0.30	19.42 *	109.99 *
Crosses	5	0.03	0.01	0.10 **	0.18	13.13	44.85
GCA	3	0.02	0.01	0.03	0.18	16.75	61.29
SCA	2	0.06	0.01	0.20 *	0.19	7.70	20.19
Varieties x L	3	0.05	0.03	0.01	0.01	11.85 *	22.39
(Varieties vs. Crosses) x L	1	0.08	0.03	0.25 *	0.13	0.05	0.15
Crosses x L	5	0.03	0.01	0.01	0.14	9.86	10.27
GCA x L	3	0.02	0.01	0.01	0.06	14.91 *	13.15
SCA x L	2	0.06	0.01	0.01	0.27 *	2.28	5.95
SCA : GCA		4.00	1.00	6.50	1.03	0.46	0.33

*, ** Significant at the 0.05 and 0.01 probability levels, respectively.

Appendix Table 8B Estimates of variety effects (v_i) from Gardner-Eberhart Analysis II of six traits from four populations per se and their six diallel crosses, from data combined over two locations in the 2002 late rainy season.

Populations	Seed. vigor	Husk cover	Aspect: Plant	Aspect: Ear	Rotten ears	Ears $Plant^{-1}$
	v_i					
	(1-5)				%	
AC0	-0.06	0.02	0.00	0.03	0.13	0.51
AC1	0.00	0.08 *	0.00	-0.09	-2.10	2.99
BC0	0.06	-0.05	0.19	0.09	2.42 *	-2.52
BC1	0.00	-0.05	-0.19	-0.03	-0.45	-0.98
SE†	0.07	0.03	0.13	0.10	1.18	2.77

† Standard error.
* Significant at the 0.05 probability level.

Appendix Table 9B Estimates of variety heterosis effects (h_i) and average heterosis ($\bar{h}$) from Gardner-Eberhart Analysis II of six traits from four populations per se and their six diallel crosses, from data combined over two locations in the 2002 late rainy season.

Populations	Seed. vigor	Husk cover	Aspect: Plant	Aspect: Ear	Rotten ears	Ears $Plant^{-1}$
	h_i					
	(1-5)				%	
AC0	-0.02	-0.02	0.06	0.03	-0.41	2.10
AC1	0.02	-0.02	-0.03	0.03	2.57 *	-1.18
BC0	-0.02	0.01	-0.09	0.06	-1.89	-1.14
BC1	0.02	0.04	0.06	-0.13	-0.27	0.22
$\bar{h}$	-0.09	-0.04	0.00	-0.13	-1.01	2.39
SE† for h_i	0.06	0.03	0.12	0.09	1.02	2.40
SE for $\bar{h}$	0.05	0.02	0.10	0.08	0.88	2.06

† Standard error.
* Significant at the 0.05 probability level.

Appendix Table 10B Estimates of gca and sca effects from Gardner-Eberhart Analysis III of six traits of four populations per se and their six diallel crosses, from data combined over two locations in the 2002 late rainy season.

Traits	**Populations**	**AC0**	**AC1**	**BC0**	**BC1**	**GCA effects**
		SCA effects				
Seedling vigor	AC0		0.06	-0.06	0.00	-0.05
(1-5)	AC1			0.00	-0.06	0.02
	BC0				0.06	0.02
	BC1					0.02
	SE† (gca effects)	0.05				
	SE (sca effects)	0.05				
Husk cover	AC0		-0.01	0.02	-0.01	-0.02
(1-5)	AC1			-0.01	0.02	0.02
	BC0				-0.01	-0.02
	BC1					0.02
	SE (gca effects)	0.02				
	SE (sca effects)	0.02				
Plant aspect	AC0		-0.03	0.13	-0.09	0.06
(1-5)	AC1			-0.09	0.13	-0.03
	BC0				-0.03	0.00
	BC1					-0.03
	SE (gca effects)	0.09				
	SE (sca effects)	0.09				
Ear aspect	AC0		0.13	-0.06	-0.06	0.05
(1-5)	AC1			-0.06	-0.06	-0.02
	BC0				0.13	0.11
	BC1					-0.14
	SE (gca effects)	0.07				
	SE (sca effects)	0.07				
Rotten ears	AC0		0.70	-0.01	-0.69	-0.35
(%)	AC1			-0.69	-0.01	1.52
	BC0				0.70	-0.68
	BC1					-0.49
	SE (gca effects)	0.84				
	SE (sca effects)	0.79				
Ears plant^{-1}	AC0		-1.28	0.49	0.80	2.36
(%)	AC1			0.80	0.49	0.31
	BC0				-1.28	-2.40
	BC1					-0.28
	SE (gca effects)	1.96				
	SE (sca effects)	1.85				

† Standard error.

Appendix Table 11B Mean squares from analyses of variance of five traits of the testcrosses of AC1-S_1 at Suwan Farm in the 2003 early rainy season.

Source of variation	df	Husk cover	Aspect Plant	Aspect Ear	Rotten ears	Ears $Plant^{-1}$
		(1-5)			%	
Replications (Rep.)	1	0.31	2.32	8.38	0.21	376.85
Blocks/rep. (adj.)	30	0.18	0.49	0.62	0.70	49.16
Treatments (unadj.)	255	0.31 **	0.60	0.26	0.81	47.33
Treatments (adj.)	255	-	0.56 **	0.23 **	-	-
Intra-block error	225	0.15	0.21	0.15	0.87	52.64
CV (%)		24.13	20.69	20.69	611.81	7.70

** Significant at the 0.01 probability level.

Appendix Table 12B Mean squares from analyses of variance of five traits of the testcrosses of BC1-S_1 at Suwan Farm in the 2003 early rainy season.

Source of variation	df	Husk cover	Aspect Plant	Aspect Ear	Rotten ears	Ears $Plant^{-1}$
		(1-5)			%	
Replications (Rep.)	1	0.60	0.00	0.60	7.39	3306.82
Blocks/rep. (adj.)	30	0.54	0.72	0.40	1.92	63.98
Treatments (unadj.)	255	0.31	0.75	0.45	1.09	64.43
Treatments (adj.)	255	0.28 **	0.64 **	0.40 **	1.02	-
Intra-block error	225	0.17	0.27	0.20	0.93	51.24
CV (%)		27.44	21.31	19.58	407.94	7.82

** Significant at the 0.01 probability level.

Appendix Table 13B Means of 15 traits and grain type of the 25 top-yielders of the testcrosses of AC1-S_1 at Suwan Farm in the 2003 early rainy season.

	Grain yield	Relat.	Days to 50%		Height		Lodging		Foliar	Husk	Aspect		Rotten	Ears	Grain	Grain	Grain
Entry	at 15% moist.	to check	Ant.	Silk.	Plant	Ear	Stalk	Root	dis.	cover	Plant	Ear	ears	Plant^{-1}	moist.	shell.	type
	kg ha^{-1}	%	d		cm		%	(1-5)					%				
AC1-S_1-180-2 x Ki 47	9,415	208	56	57	236	137	16	0.9	2.0	1.8	2.0	1.8	0	104	25.98	84.60	OY^SF
AC1-S_1-21-9 x Ki 47	9,177	202	56	57	249	147	4	1.0	2.2	1.5	1.2	1.9	0	92	28.29	87.47	OY^F
AC1-S_1-86-10 x Ki 47	9,173	202	56	57	244	136	16	1.6	2.3	1.0	2.3	2.1	2	104	25.60	83.50	YOSF
AC1-S_1-21-2 x Ki 47	9,155	202	56	57	250	154	8	1.2	2.3	1.3	1.2	1.5	0	94	25.99	84.19	OY^F
AC1-S_1-204-14 x Ki 47	9,079	200	56	56	238	140	18	1.4	2.0	2.0	1.7	1.7	0	98	26.32	85.78	OY^F
AC1-S_1-72-17 x Ki 47	9,070	200	56	57	259	151	4	1.0	2.0	1.3	1.5	1.8	0	104	28.19	81.03	OY^F
AC1-S_1-228-8 x Ki 47	9,015	199	56	56	261	160	6	1.0	3.1	1.5	1.8	1.3	0	92	25.01	86.76	OY^F
AC1-S_1-57-12 x Ki 47	8,911	197	56	57	252	146	8	1.3	2.3	1.0	2.3	1.8	0	100	26.70	81.49	OYF
AC1-S_1-57-4 x Ki 47	8,890	196	57	57	253	152	6	1.1	2.1	1.8	1.7	1.0	0	96	26.52	83.28	OYF
AC1-S_1-175-13 x Ki 47	8,886	196	58	57	255	157	10	1.4	2.1	2.0	2.0	2.0	0	90	26.88	83.66	OY^F
AC1-S_1-72-5 x Ki 47	8,883	196	56	57	252	150	21	1.2	2.1	2.3	2.3	1.9	0	96	25.77	87.23	OY^F
AC1-S_1-228-13 x Ki 47	8,865	195	56	56	237	153	22	2.2	2.8	2.0	2.7	2.1	0	98	24.69	81.97	OY^F
AC1-S_1-146-17 x Ki 47	8,856	195	58	58	250	143	17	1.4	2.1	1.0	1.7	1.7	0	92	27.91	83.65	OY^SF
AC1-S_1-14-11 x Ki 47	8,845	195	56	57	249	142	10	1.6	2.2	1.8	1.9	1.9	0	100	26.33	83.30	OYF
AC1-S_1-159-19 x Ki 47	8,818	194	57	57	256	150	8	2.0	1.9	2.0	1.5	1.5	0	99	26.74	83.75	OYF
AC1-S_1-228-3 x Ki 47	8,750	193	57	57	262	151	2	2.2	2.1	1.3	2.1	1.8	0	98	24.37	82.22	OY^F
AC1-S_1-245-20 x Ki 47	8,723	192	56	56	246	148	6	1.0	2.5	1.3	2.6	1.8	0	96	25.73	83.10	OYF
AC1-S_1-55-9 x Ki 47	8,701	192	57	57	258	148	6	1.9	2.8	1.0	1.9	1.6	0	96	27.06	84.43	OY^F
AC1-S_1-86-1 x Ki 47	8,675	191	58	58	243	143	6	1.0	2.2	1.5	1.4	1.8	0	90	26.35	87.70	OY^F
AC1-S_1-204-6 x Ki 47	8,666	191	57	58	256	150	4	2.2	3.0	1.5	2.6	1.7	0	92	25.08	84.63	OF
AC1-S_1-86-13 x Ki 47	8,649	191	56	56	242	136	20	1.4	2.8	2.0	2.6	1.9	0	102	23.41	84.59	OY^F
AC1-S_1-245-17 x Ki 47	8,617	190	57	57	256	149	6	1.5	2.4	1.5	1.6	1.4	0	98	25.04	79.15	OY^F
AC1-S_1-83-18 x Ki 47	8,610	190	57	56	263	159	14	2.3	2.1	1.5	2.2	2.2	0	92	22.96	87.52	YOSF
AC1-S_1-88-15 x Ki 47	8,598	190	57	57	251	148	13	1.1	1.9	1.3	1.3	1.8	0	92	27.49	86.99	OY^F
AC1-S_1-88-13 x Ki 47	8,588	189	57	57	258	148	22	1.2	3.5	1.3	3.0	2.3	0	102	24.27	85.28	OY^F
KSX 4501	6,388	141	56	56	238	141	24	1.7	3.0	1.8	3.2	3.2	0	100	22.39	80.56	YOF
KSX 4505	7,598	168	56	57	251	153	45	1.7	3.3	1.8	3.7	1.4	0	96	23.67	82.84	OYF
KSX 4507	7,700	170	58	58	245	150	22	1.4	3.0	2.3	3.1	2.3	0	100	23.11	86.36	OY^F
BIG 949	6,141	135	56	58	233	134	4	2.8	2.8	2.0	3.0	2.1	0	94	28.09	79.42	OY^F
KSX 4452 (Suwan 4452)	6,679	147	56	57	248	149	56	1.5	2.8	1.5	2.7	2.4	0	100	23.41	78.49	OYF
Suwan 3851 (Check)	4,535	100	56	56	239	139	21	1.3	3.4	2.3	3.9	3.5	0	88	26.11	82.74	YOF
Mean	8,408	185	57	57	249	147	14	1.5	2.5	1.6	2.2	1.9	0	97	25.66	83.80	
LSD 0.05	1,616.79		1.33	1.27	14.40	12.61	15.58	0.89	0.63	0.75	0.93	0.80	1.84	14.29	2.25	6.15	
LSD 0.01	2,130.68		1.76	1.67	18.98	16.62	20.53	1.17	0.83	0.99	1.23	1.06	2.42	18.83	2.97	8.10	

Appendix Table 14B Means of 15 traits and grain type of the 25 top-yielders of the testcrosses of BC1-S_1 at Suwan Farm in the 2003 early rainy season.

Entry	Grain yield	Relat.	Days to 50%		Height		Lodging		Foliar	Husk	Aspect		Rotten	Ears	Grain	Grain	Grain
	at 15% moist.	to check	Ant.	Silk.	Plant	Ear	Stalk	Root	dis.	cover	Plant	Ear	ears	Plant^{-1}	moist.	shell.	type
	kg ha^{-1}	%	d		cm		%		(1-5)				%				
BC1-S_1-184-16 x Ki 46	9,975	143	57	57	248	140	4	1.3	1.9	1.3	1.3	1.6	0	93	22.78	83.27	OYF
BC1-S_1-186-16 x Ki 46	9,633	139	56	56	243	140	8	2.4	2.1	1.3	2.3	2.0	2	106	22.37	81.67	OYF
BC1-S_1-71-1 x Ki 46	9,408	135	56	57	241	138	0	1.2	2.1	1.2	1.7	2.8	0	96	24.27	82.12	OY^F
BC1-S_1-47-9 x Ki 46	9,270	133	56	56	237	131	10	1.2	2.4	1.4	2.6	2.0	2	102	23.00	84.61	OYF
BC1-S_1-90-7 x Ki 46	9,254	133	57	58	253	155	6	1.8	2.5	1.4	1.6	1.6	0	92	23.79	82.35	OYF
BC1-S_1-186-3 x Ki 46	9,236	133	56	56	245	147	12	2.2	2.4	1.1	2.2	2.8	0	100	22.70	87.36	OYF
BC1-S_1-115-9 x Ki 46	9,228	133	57	57	245	141	0	1.2	2.2	1.4	1.2	1.7	0	94	23.72	81.42	OYF
BC1-S_1-222-20 x Ki 46	9,167	132	57	57	242	148	10	1.6	2.4	1.5	2.4	2.2	0	98	24.45	78.56	OYF
BC1-S_1-246-11 x Ki 46	9,163	132	57	57	235	141	6	1.0	2.3	1.6	1.6	1.9	0	94	23.30	78.91	OY^F
BC1-S_1-32-19 x Ki 46	9,131	131	56	56	241	143	4	1.1	2.5	1.8	1.9	1.2	0	98	24.07	78.44	OYF
BC1-S_1-296-19 x Ki 46	9,093	131	56	56	235	141	16	1.5	2.5	1.9	1.8	1.9	0	96	23.52	81.28	OYF
BC1-S_1-32-20 x Ki 46	9,038	130	56	56	229	132	12	1.0	2.5	1.5	1.4	2.4	0	92	25.05	83.12	OYF
BC1-S_1-186-20 x Ki 46	9,034	130	56	56	247	147	8	1.9	2.2	1.5	2.0	1.6	3	92	23.50	83.19	OYF
BC1-S_1-184-9 x Ki 46	9,022	130	57	57	236	136	2	1.2	2.2	1.8	1.8	2.1	0	102	22.46	79.78	OYF
BC1-S_1-280-3 x Ki 46	8,979	129	57	57	241	141	12	1.9	2.5	1.5	2.4	2.0	0	98	21.52	77.00	OYF
BC1-S_1-115-7 x Ki 46	8,960	129	57	57	247	146	8	1.7	2.2	1.0	1.4	1.6	0	94	24.48	78.48	OYF
BC1-S_1-37-6 x Ki 46	8,924	128	57	56	243	141	6	1.3	2.7	1.3	3.1	2.7	0	98	24.80	83.26	OYF
BC1-S_1-172-19 x Ki 46	8,904	128	56	56	249	137	4	1.3	2.5	1.6	2.4	3.0	0	100	22.53	82.84	OYF
BC1-S_1-90-12 x Ki 46	8,874	128	56	56	245	139	2	1.3	2.1	1.2	1.6	2.5	0	102	23.29	79.21	OY^F
BC1-S_1-115-19 x Ki 46	8,846	127	57	57	246	144	17	1.5	2.1	1.4	1.4	1.9	0	96	23.33	82.94	OYF
BC1-S_1-115-6 x Ki 46	8,832	127	57	56	242	138	18	1.8	2.4	1.1	1.6	1.5	0	102	24.18	82.96	OYF
BC1-S_1-90-2 x Ki 46	8,818	127	57	57	232	127	12	1.1	2.1	0.8	1.4	1.5	0	98	23.67	81.14	OYF
BC1-S_1-184-4 x Ki 46	8,798	127	56	57	246	127	6	1.6	2.2	2.3	1.3	1.3	0	94	24.78	79.40	OYF
BC1-S_1-71-22 x Ki 46	8,795	127	56	56	229	126	4	1.4	2.3	1.1	1.5	1.7	0	102	23.67	82.64	OYF
BC1-S_1-296-2 x Ki 46	8,787	126	57	57	250	149	4	1.8	2.6	1.2	1.9	2.0	0	100	24.78	80.31	OYF
KSX 4501	6,600	95	56	56	238	142	24	1.5	2.2	1.4	3.0	2.2	0	106	21.73	73.79	OY^F
KSX 4505	6,958	100	57	57	246	154	57	1.7	3.2	1.5	3.5	1.7	0	104	21.09	79.43	OYF
KSX 4507	7,523	108	57	57	251	149	18	2.0	3.1	1.8	3.3	2.6	0	96	21.17	83.54	OY^F
BIG 949	4,940	71	58	58	234	128	34	3.3	2.7	1.6	3.6	3.1	0	85	24.93	78.18	OF
KSX 4452 (Suwan 4452)	8,838	127	57	57	239	152	29	1.2	2.2	1.1	2.1	1.8	0	100	24.32	80.97	OF
Suwan 3851 (Check)	6,952	100	56	56	243	144	6	1.3	2.9	1.4	3.4	2.2	0	88	22.52	81.90	OF
Mean	8,677	125	57	57	242	141	12	1.6	2.4	1.4	2.1	2.0	0	97	23.41	81.10	
LSD 0.05	1,734.22		1.45	1.48	16.16	12.32	15.78	0.99	0.77	0.84	1.07	0.91	1.95	14.10	1.95	5.41	
LSD 0.01	2,286.27		1.91	1.96	21.31	16.24	20.79	1.30	1.01	1.10	1.41	1.20	2.58	18.58	2.57	7.13	

Appendix Table 15B Mean squares from analyses of variance of eight traits of 27 populations and three population checks from data combined over two locations in the 2005 early rainy season.

Source of variation	df	Seed. vigor	Husk cover	Aspect Plant	Aspect Ear	Rotten ears	Ears Plant^{-1}	Corn borer	
		(1-5)	(1-5)	(1-5)	(1-5)	%	%	(1-5)	%
Locations (L)	1	0.57 **	0.90 **	0.19 *	0.20 *	87.72 **	1.15 ns	77.07 **	107717.68 **
Treatments (T)	29	0.03 *	0.01 ns	0.03 ns	0.06 ns	3.50 ns	15.21 ns	0.14 ns	10.09 ns
Populations per se	5	0.03 *	0.02 ns	0.06 *	0.03 ns	1.28 ns	37.85 ns	0.18 ns	20.06 ns
C0 populations per se	1	0.06 **	0.01 ns	0.08 *	0.03 ns	0.37 ns	0.00 ns	0.00 ns	39.08 ns
C1 populations per se	1	0.06 **	0.03 ns	0.02 ns	0.09 ns	2.97 ns	124.75 *	0.30 ns	1.50 ns
C2 populations per se	1	0.00 ns	0.03 ns	0.00 ns	0.00 ns	2.88 ns	1.40 ns	0.00 ns	54.54 ns
C0 vs. C1 and C2 populations per se	1	0.01 ns	0.00 ns	0.14 *	0.00 ns	0.06 ns	5.71 ns	0.02 ns	0.09 ns
C1 vs. C2 populations per se	1	0.03 *	0.06 ns	0.05 ns	0.01 ns	0.13 ns	57.40 *	0.57 ns	5.12 ns
Population crosses	14	0.03 ns	0.01 ns	0.02 ns	0.04 ns	3.39 ns	5.48 ns	0.04 ns	5.74 ns
Population topcrosses	5	0.01 ns	0.02 ns	0.03 ns	0.04 ns	2.30 ns	24.30 ns	0.38 ns	12.69 ns
C0 population topcrosses	1	0.01 ns	0.01 ns	0.03 ns	0.05 ns	0.19 ns	12.68 ns	0.31 ns	3.84 ns
C1 population topcrosses	1	0.03 ns	0.06 ns	0.12 ns	0.04 ns	1.26 ns	0.11 ns	0.01 ns	50.62 ns
C2 population topcrosses	1	0.01 ns	0.01 ns	0.00 ns	0.00 ns	3.36 ns	46.80 ns	1.53 ns	8.90 ns
C0 vs. C1 and C2 population topcrosses	1	0.00 ns	0.02 ns	0.01 ns	0.10 ns	0.93 ns	5.53 ns	0.02 ns	0.08 ns
C1 vs. C2 population topcrosses	1	0.00 ns	0.00 ns	0.01 ns	0.02 ns	5.77 ns	56.39 *	0.01 ns	0.00 ns
Checks	2	0.04 ns	0.02 ns	0.00 ns	0.00 ns	0.23 ns	0.73 ns	0.19 ns	0.49 ns
All populations vs. Checks	1	0.00 ns	0.00 ns	0.06 ns	0.36 *	0.90 ns	6.36 ns	0.00 ns	31.30 ns
Population per se vs. Population crosses and topcrosses	1	0.01 ns	0.00 ns	0.01 ns	0.21 *	20.97 **	2.70 ns	0.24 ns	1.98 ns
Population crosses vs. Population topcrosses	1	0.12 ns	0.01 ns	0.03 ns	0.34 *	13.69 ns	43.23 ns	0.01 ns	14.24 ns
T x L	29	0.01 ns	0.01 ns	0.03 ns	0.03 ns	3.84 ns	10.26 ns	0.14 ns	13.32 ns
Populations per se x L	5	0.00 ns	0.01 ns	0.01 ns	0.02 ns	7.22 ns	7.87 ns	0.18 ns	19.16 ns
Population crosses x L	14	0.02 ns	0.01 ns	0.03 ns	0.03 ns	3.77 ns	9.92 ns	0.04 ns	9.96 ns
Population topcrosses x L	5	0.02 ns	0.02 ns	0.08 ns	0.09 ns	1.73 ns	7.51 ns	0.38 ns	11.35 ns
Checks x L	2	0.00 ns	0.02 ns	0.00 ns	0.00 ns	3.79 ns	20.09 ns	0.19 ns	4.35 ns
(All populations vs. Checks) x L	1	0.01 ns	0.00 ns	0.09 ns	0.00 ns	2.95 ns	2.82 ns	0.00 ns	57.87 ns
(Population per se vs. Population crosses and topcrosses) x L	1	0.00 ns	0.00 ns	0.02 ns	0.00 ns	0.00 ns	0.30 ns	0.24 ns	25.73 ns
(Population crosses vs. Population topcrosses) x L	1	0.00 ns	0.01 ns	0.02 ns	0.00 ns	3.16 ns	38.50 ns	0.01 ns	2.06 ns
Pooled error	86	0.05	0.03	0.05	0.09	9.18	32.10	0.28	46.58
CV (%)		9.79	9.35	6.65	10.71	45.14	3.22	17.37	8.18

*, ** Significant at the 0.05 and 0.01 probability levels, respectively; ns, not significant.

Appendix Table 16B Means of 18 traits and grain type of 27 populations and three population checks from data combined over two locations in the 2005 early rainy season.

Entry	Grain yield at 15% moist.	Relat. to check	Seed. vigor	Days to 50% Ant.	Days to 50% Silk.	Height Plant	Height Ear	Lodging Stalk	Lodging Root	Foliar dis.	Husk cover	Aspect Plant	Aspect Ear	Rotten ears	Ears $Plant^{-1}$	Grain moist.	Grain shell.	Grain type	Corn borer	
	kg ha^{-1}	%	(1-5)	d		cm		%	(1-5)					%					(1-5)	%
AC2	6,625	101	1.1	52	53	242	135	6	2.5	2.6	1.2	2.6	1.8	6	103	20.08	82.23	OYF	2.0	39
BC0	6,545	100	1.1	51	52	228	133	1	2.8	2.8	1.1	2.8	1.7	6	98	19.16	81.75	OY^FSF	2.3	41
BC2	6,477	99	1.1	52	52	243	137	3	2.1	2.6	1.0	2.6	1.8	5	102	19.27	82.35	OY^FSF	2.0	47
AC1	6,349	97	1.3	52	52	237	131	1	2.6	2.7	1.3	2.7	1.7	5	91	19.39	81.25	OYF	2.2	44
BC1	6,197	95	1.1	51	52	234	132	4	2.5	2.8	1.2	2.8	2.0	6	102	18.46	82.50	OY^FSF	2.8	45
AC0	5,938	91	1.3	51	51	239	136	10	2.3	3.0	1.2	3.0	1.9	5	98	19.09	82.51	OYF	2.3	47
BC2 x AC1	7,329	112	1.2	52	52	248	144	3	2.4	2.6	1.3	2.6	1.6	3	102	19.95	83.12	OY^FSF	2.2	46
AC2 x BC2	7,200	110	1.0	51	52	247	139	4	2.5	2.7	1.0	2.7	1.7	2	101	19.93	83.06	OY^FSF	1.8	45
AC2 x BC1	7,139	109	1.1	51	52	248	144	1	2.4	2.7	1.1	2.7	1.7	3	100	19.89	82.60	OY^FSF	2.0	45
AC1 x BC0	7,122	109	1.3	51	52	239	138	3	2.6	2.6	1.2	2.6	1.5	6	100	19.55	82.05	OY^FSF	1.9	43
AC1 x BC1	7,093	109	1.1	51	52	243	139	6	2.3	2.7	1.2	2.7	1.6	6	100	19.53	82.60	OYFSF	2.0	45
AC0 x BC0	7,029	108	1.1	51	52	240	141	7	2.5	2.6	1.1	2.6	1.5	4	98	19.20	82.86	OY^FSF	2.3	47
BC1 x AC0	6,997	107	1.0	51	52	239	139	8	2.3	2.9	1.1	2.9	1.7	3	103	18.87	82.90	OY^FSF	2.2	43
AC2 x BC0	6,937	106	1.3	51	52	237	136	5	2.5	2.6	1.2	2.6	1.7	4	98	19.41	82.43	OY^FSF	2.2	48
BC2 x AC0	6,795	104	1.1	51	52	248	144	6	2.4	2.9	1.1	2.9	1.8	4	101	18.67	83.39	OY^FSF	2.1	45
BC2 x BC0	6,723	103	1.1	52	53	234	133	5	2.3	2.7	1.0	2.7	1.8	5	98	19.72	83.37	OY^FSF	2.2	45
BC2 x BC1	6,583	101	1.3	53	53	241	138	4	2.3	2.7	1.2	2.7	1.7	4	101	19.33	82.89	OY^FSF	2.1	44
BC1 x BC0	6,490	99	1.2	51	52	227	132	4	2.6	2.9	1.3	2.9	1.8	4	99	18.86	83.60	OY^FSF	2.3	46
AC1 x AC0	6,472	99	1.3	51	52	239	137	9	2.4	2.8	1.2	2.8	2.0	4	103	18.59	83.25	OYF	2.1	41
AC2 x AC1	6,302	96	1.4	52	53	244	135	5	2.5	2.8	1.1	2.8	1.7	6	98	19.52	80.88	OYF	2.0	46
AC2 x AC0	6,113	94	1.1	52	53	243	133	5	2.2	2.8	1.1	2.8	1.9	6	100	18.84	81.82	OYFSF	1.9	44
Ki 46 x BC2	8,150	125	1.3	51	51	235	135	2	2.2	2.6	1.1	2.6	1.5	3	92	19.52	82.17	OY^F	1.4	42
Ki 47 x AC1	8,007	123	1.2	51	51	245	145	3	2.5	2.9	1.3	2.9	1.5	4	101	19.63	84.69	OY^FSF	2.2	47
Ki 46 x BC1	7,937	122	1.3	51	51	232	134	4	2.4	2.5	1.0	2.5	1.3	3	101	18.96	81.82	OY^F	2.1	40
Ki 46 x BC0	7,589	116	1.3	50	50	222	128	4	2.3	2.6	1.2	2.6	1.8	3	95	18.66	81.91	OY^F	1.9	42
Ki 47 x AC0	7,279	111	1.3	50	51	240	140	2	2.6	2.8	1.3	2.8	1.5	4	99	18.70	84.02	OY^FSF	2.5	44
Ki 47 x AC2	7,165	110	1.3	50	51	245	143	3	2.9	2.7	1.2	2.7	1.5	1	99	19.27	83.92	OY^FSF	2.7	45
Suwan3(S)C4	6,589	101	1.1	51	51	232	130	5	2.4	2.8	1.2	2.8	1.9	4	100	18.48	82.17	OYF	2.0	47
Suwan1(S)C12-F_3	6,099	93	1.3	51	52	228	125	9	2.3	2.8	1.2	2.8	2.0	4	101	18.54	83.22	OYF	2.5	47
Suwan5(S)C4-F_2 (Check)	6,532	100	1.1	52	52	230	130	8	2.2	2.8	1.0	2.8	2.0	4	100	18.96	83.70	OYFSF	1.9	46
Mean	6,860	105	1.2	51	52	238	136	5	2.4	2.7	1.1	2.7	1.7	4	100	19.20	82.70		2.1	45
LSD 0.05	726.47		0.24	1.42	1.85	9.95	6.73	6.36	0.61	0.37	0.22	0.37	0.38	4.01	6.55	1.11	2.25		0.76	7.46
LSD 0.01	979.07		0.32	1.91	2.49	13.41	9.07	8.57	0.83	0.50	0.29	0.50	0.51	5.40	8.83	1.50	3.03		1.02	10.06

Appendix Table 17B Mean squares from Gardner-Eberhart Analysis II and Analysis III of eight traits from six populations per se and their 15 diallel crosses, from data combined over two locations in the 2005 early rainy season.

Source of variation	df	Seed. vigor	Husk cover	Aspect Plant	Aspect Ear	Rotten ears	Ears Plant^{-1}	Corn borer	
		(1-5)				%		(1-5)	%
Gardner-Eberhart Analysis II									
Varieties	5	0.14	0.09	0.13	0.09	4.65	54.94	1.27	128.03
Heterosis	15	0.08	0.03	0.07	0.11	11.44	37.27	0.54	179.85
Average heterosis	1	0.00	0.02	0.00	0.24	33.28	35.79	0.54	0.02
Variety heterosis	5	0.10	0.03	0.06	0.07	6.61	86.52 **	0.81	305.27
Specific heterosis	9	0.08	0.03	0.09	0.12	11.69	10.07	0.40	130.16
Varieties x L	5	0.04	0.05	0.06	0.09	5.32	38.94	1.27	211.21
Heterosis x L	15	0.04	0.02	0.06	0.09	16.06	23.74	0.54	153.85
Average heterosis x L	1	0.00	0.00	0.06	0.00	0.74	15.91	0.54	110.72
Variety heterosis x L	5	0.03	0.02	0.02	0.13	23.48 *	5.47	0.81	318.50 *
Specific heterosis x L	9	0.05	0.02	0.09	0.07	13.64	34.76	0.40	67.18
Gardner-Eberhart Analysis III									
Varieties	5	0.10 *	0.07	0.16 *	0.07	3.85	113.57	1.31	158.48
Varieties vs. Crosses	1	0.00	0.02	0.00	0.24	33.28	35.79	0.54	0.02
Crosses	14	0.10	0.03	0.06	0.11	10.16	16.44	0.53	181.82
GCA	5	0.13	0.04	0.03	0.08	7.41	27.89	0.77	274.82
SCA	9	0.08	0.03	0.09	0.12	11.69	10.07	0.40	130.16
Varieties x L	5	0.01	0.03	0.02	0.10	21.66 *	23.61	1.31	160.59
(Varieties vs. Crosses) x L	1	0.00	0.00	0.06	0.00	0.74	15.91	0.54	110.72
Crosses x L	14	0.05	0.03	0.07	0.09	11.32	29.77	0.53	175.01
GCA x L	5	0.06	0.04	0.05	0.13	7.15	20.80	0.77	369.12 *
SCA x L	9	0.05	0.02	0.09	0.07	13.64	34.76	0.40	67.18
SCA : GCA		0.60	0.79	3.07	1.55	1.58	0.36	0.52	0.47

*, ** Significant at the 0.05 and 0.01 probability levels, respectively.

Appendix Table 18B Estimates of variety effects (v_i) from Gardner-Eberhart Analysis II of eight traits from six populations per se and their 15 diallel crosses, from data combined over two locations in the 2005 early rainy season.

Populations	v_i							
	Seed. vigor	Husk cover	Aspect Plant	Aspect Ear	Rotten ears	Ears Plant^{-1}	Corn borer	
	(1-5)				%		(1-5)	%
AC0	0.17	0.01	0.26 **	0.10	-0.20	-0.95	-0.11	3.50
AC1	0.17	0.18 *	-0.07	-0.07	-1.04	-7.78 **	0.22	1.92
AC2	-0.08	0.01	-0.15	-0.07	0.93	3.76	-0.61	-9.59
BC0	-0.08	-0.07	0.01	-0.07	0.41	-1.00	0.39	0.73
BC1	-0.08	0.01	0.10	0.18	0.68	3.39	0.56	4.69
BC2	-0.08	-0.15	-0.15	-0.07	-0.77	2.57	-0.44	-1.25
SE†	0.09	0.08	0.09	0.12	1.32	2.09	0.57	18.24

† Standard error.

*, ** Significant at the 0.05 and 0.01 probability levels, respectively.

Appendix Table 19B Estimates of variety heterosis effects (h_i) and average heterosis ($\bar{h}$) from Gardner-Eberhart Analysis II of eight traits from six populations per se and their 15 diallel crosses, from data combined over two locations in the 2005 early rainy season.

Populations	h_i							
	Seed. vigor	Husk cover	Aspect Plant	Aspect Ear	Rotten ears	Ears Plant^{-1}	Corn borer	
	(1-5)				%		(1-5)	%
AC0	-0.16 **	-0.03	-0.10	0.05	0.29	1.35	-0.03	-5.35
AC1	0.03	-0.03	0.03	0.01	1.20	4.76 **	0.01	1.47
AC2	0.07	-0.06	0.05	0.07	-0.72	-2.79	0.26	5.88
BC0	0.09	0.05	-0.06	-0.01	0.31	-1.25	0.10	3.76
BC1	-0.01	0.03	-0.01	-0.14	-0.68	-1.25	-0.49	-6.83
BC2	-0.01	0.05	0.09	0.03	-0.39	-0.82	0.14	1.06
$\bar{h}$	-0.01	-0.03	0.00	-0.10	-1.14	1.18	-0.14	-0.03
SE† for h_i	0.06	0.06	0.06	0.09	0.93	1.48	0.40	12.90
SE for $\bar{h}$	0.05	0.04	0.05	0.06	0.70	1.11	0.30	9.65

† Standard error.

** Significant at the 0.01 probability level.

Appendix Table 20B Estimates of gca and sca effects from Gardner-Eberhart Analysis III of eight traits of six populations per se and their 15 diallel crosses, from data combined over two locations in the 2005 early rainy season.

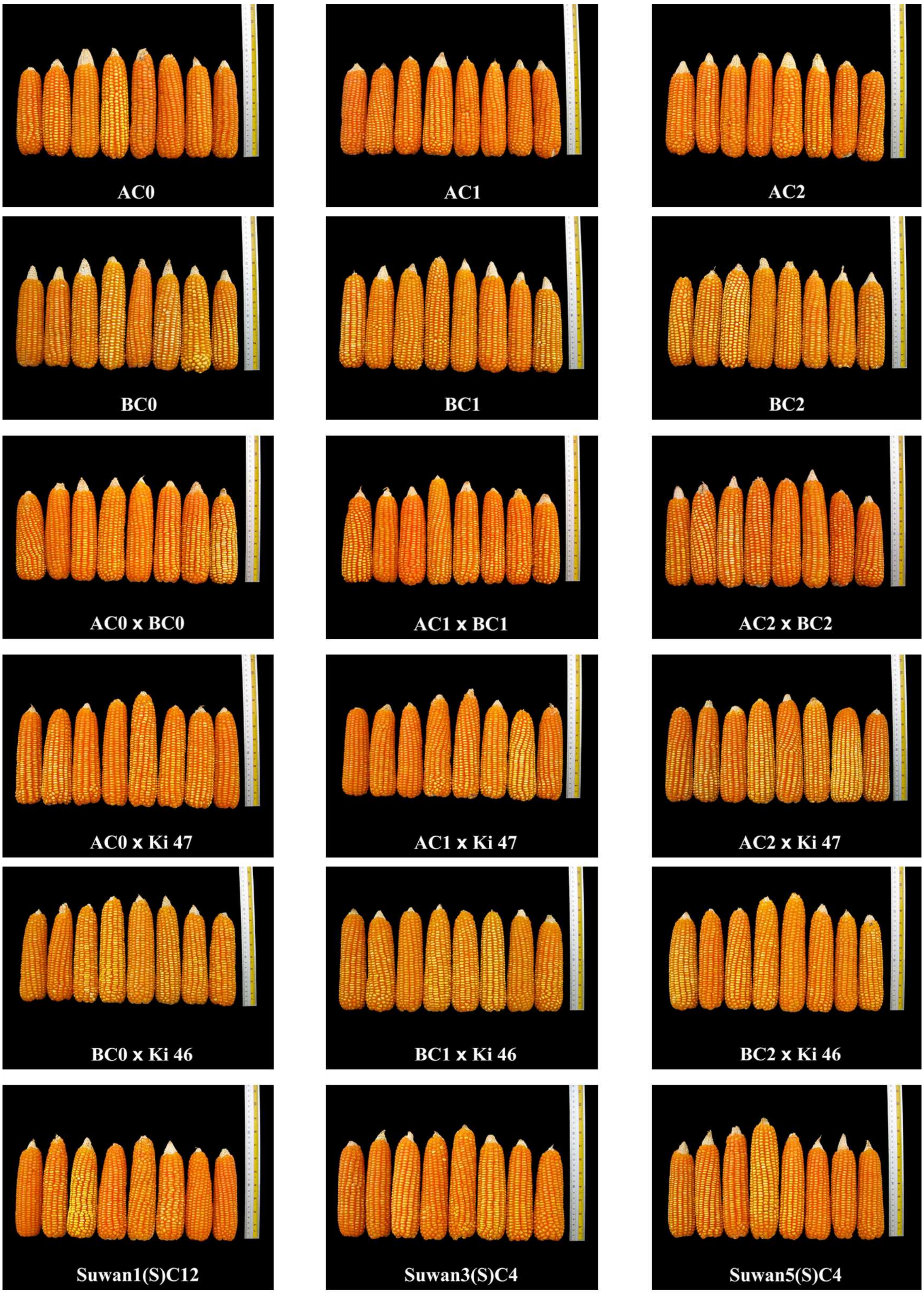
Traits	Populations	AC0	AC1	AC2	BC0	BC1	BC2	GCA effects
		SCA effects						
Seedling	AC0		0.05	-0.03	-0.05	-0.03	0.05	-0.08
vigor	AC1			0.12	0.01	-0.13	-0.05	0.11 *
(1-5)	AC2				0.10	-0.05	-0.13	0.03
	BC0					-0.01	-0.07	0.05
	BC1						0.20 **	-0.06
	BC2							-0.06
	SE† (gca effects)		0.04					
	SE (sca effects)		0.07					
Husk	AC0		0.02	0.04	-0.03	-0.05	0.02	-0.03
cover	AC1			-0.05	-0.03	-0.05	0.10	0.06
(1-5)	AC2				0.08	-0.03	-0.05	-0.05
	BC0					-0.08	-0.11	0.01
	BC1						0.04	0.03
	BC2							-0.03
	SE (gca effects)		0.04					
	SE (sca effects)		0.07					
Plant	AC0		-0.02	0.00	-0.14	0.03	0.13	0.03
aspect	AC1			0.13	-0.02	-0.02	-0.08	-0.01
(1-5)	AC2				-0.08	-0.08	0.03	-0.03
	BC0					-0.19 *	0.05	-0.05
	BC1						-0.12	0.03
	BC2							0.01
	SE (gca effects)		0.05					
	SE (sca effects)		0.08					
Ear	AC0		0.21 *	0.06	-0.19	-0.10	0.02	0.10
aspect	AC1			0.02	-0.15	-0.06	-0.02	-0.03
(1-5)	AC2				0.04	-0.04	-0.08	0.03
	BC0					-0.21 *	0.08	-0.05
	BC1						0.00	-0.05
	BC2							-0.01
	SE (gca effects)		0.06					
	SE (sca effects)		0.10					

Appendix Table 20B (continued)

Traits	Populations	AC0	AC1	AC2	BC0	BC1	BC2	GCA effects
			SCA effects					
Rotten	AC0		-0.97	2.09	-0.73	-0.85	0.45	0.18
ears	AC1			0.87	0.07	1.15	-1.12	0.68
(%)	AC2				-0.22	-0.94	-1.80	-0.26
	BC0					0.47	1.35	0.51
	BC1						1.11	-0.34
	BC2							-0.78
	SE (gca effects)		0.66					
	SE (sca effects)		1.12					
Ears	AC0		0.90	-0.51	-0.91	1.27	-0.74	0.87
plant^{-1}	AC1			-1.75	1.07	-1.14	0.92	0.87
(%)	AC2				0.87	-0.07	1.45	-0.91
	BC0					-0.26	-1.30	-1.75
	BC1						-0.32	0.44
	BC2							0.47
	SE (gca effects)		1.04					
	SE (sca effects)		1.77					
Corn	AC0		-0.01	-0.18	0.33	-0.34	0.20	-0.08
borer	AC1			-0.05	-0.22	0.28	-0.01	0.13
(1-5)	AC2				0.12	-0.05	0.16	-0.04
	BC0					-0.12	-0.34	0.29
	BC1						-0.01	-0.21
	BC2							-0.08
	SE (gca effects)		0.29					
	SE (sca effects)		0.49					
Corn	AC0		-2.81	-2.61	4.19	-5.06	6.29	-3.60
borer	AC1			1.61	-3.41	4.40	0.21	2.43
(%)	AC2				-0.49	-0.52	2.02	1.08
	BC0					-4.71	-5.00	4.12
	BC1						-3.52	-4.48
	BC2							0.44
	SE (gca effects)		9.12					
	SE (sca effects)		15.48					

† Standard error.

*, ** Significant at the 0.05 and 0.01 probability levels, respectively.



Note: A = Suwan1(S)C11 and B = KS6(S)C3.

Appendix Figure 1B Sample ears of C0, C1 and C2 populations per se, their population crosses and their population topcrosses to inbred testers compared with three population checks (Suwan1(S)C12, Suwan3(S)C4 and Suwan5(S)C4).

APPENDIX C

ADDITIONAL DATA FOR HYBRID DEVELOPMENT

Appendix Table 1C Mean squares from analyses of variance of six traits of C0 hybrids from data combined over two locations in the 2002 late rainy season.

Source of variation	df	Seed. vigor	Husk cover	Aspect: Plant	Aspect: Ear	Rotten ears	Ears $Plant^{-1}$
		(1-5)				%	
Locations (L)	1	0.23 **	0.00	21.55 **	3.44 **	1067.02 **	1519.84 **
Treatments (T)	155	0.05 **	0.05 **	0.06 **	0.09 **	6.53	19.93
C0 hybrids	149	0.05 *	0.05 **	0.06 **	0.08 **	6.64	19.10
C0-S_4 TCHs†	49	0.05	0.05 **	0.04	0.10 **	2.59	16.08
AC0-S_4 TCHs	24	0.04	0.10 **	0.03	0.13 **	3.32	18.82
BC0-S_4 TCHs	24	0.05 *	0.00	0.05	0.05	1.92	13.90
AC0-S_4 TCHs vs. BC0-S_4 TCHs	1	0.16 *	0.15 *	0.02	0.53 **	1.21	2.37
C0-S_4 IPHs‡	99	0.05 *	0.05 **	0.06 **	0.05	7.24	20.21
C0-S_4 TCHs vs. C0-S_4 IPHs	1	0.11	0.01	0.50 **	2.83 **	144.65 **	56.69
Checks	5	0.06	0.02	0.05	0.16	3.16	2.30
C0 hybrids vs. Checks	1	0.01	0.00	0.20	0.60	7.29	231.35
T x L	155	0.03	0.03 *	0.04	0.05	6.44	17.37
C0 hybrids x L	149	0.03	0.03 *	0.03	0.05	6.58	17.31
Checks x L	5	0.02	0.02	0.08	0.06	2.71	3.23
(C0 hybrids vs. Checks) x L	1	0.02	0.04	0.07	0.01	4.15	97.82 *
Pooled error	262	0.06	0.02	0.05	0.06	8.37	24.99
CV (%)		14.97	15.14	5.99	9.89	113.29	4.36

† TCHs = testcross hybrids.

‡ IPHs = interpopulation hybrids.

*, ** Significant at the 0.05 and 0.01 probability levels, respectively.

Appendix Table 2C Means of six traits and grain type of the top 10 C0 hybrids of each group compared with Suwan 3851 (hybrid check) from data combined over two locations in the 2002 late rainy season.

Entry	Seed. vigor	Husk cover	Aspect Plant	Aspect Ear	Rotten ears	Ears $Plant^{-1}$	Grain type
	(1-5)				%		
Top 10 C0 hybrids							
AC0-S_4-88 x Ki 47	1.0	1.0	3.1	1.5	0	96	OYFSF
AC0-S_4-72 x Ki 47	1.0	1.2	3.1	2.0	1	94	OYFSF
AC0-S_4-96 x Ki 47	1.0	1.2	3.1	2.0	0	93	OYF
AC0-S_3-180 x Ki 47	1.1	1.0	3.0	2.1	4	99	YOF
AC0-S_4-159 x BC0-S_4-250	1.0	1.0	3.4	2.2	2	98	OYFSF
BC0-S_4-90 x Ki 46	1.0	1.0	3.3	2.3	0	96	YOF
AC0-S_4-228 x Ki 47	1.1	1.0	3.2	2.3	2	99	OYFSF
AC0-S_4-204 x BC0-S_4-47	1.1	1.1	3.3	2.1	0	98	OYFSF
AC0-S_4-159 x BC0-S_4-47	1.0	1.0	3.2	2.5	3	93	OYF
BC0-S_4-296 x Ki 46	1.1	1.0	3.1	2.0	2	96	OYF
Mean	1.1	1.1	3.2	2.1	1	96	
Top 10 AC0 testcross hybrids							
AC0-S_4-88 x Ki 47	1.0	1.0	3.1	1.5	0	96	OYFSF
AC0-S_4-72 x Ki 47	1.0	1.2	3.1	2.0	1	94	OYFSF
AC0-S_4-96 x Ki 47	1.0	1.2	3.1	2.0	0	93	OYF
AC0-S_3-180 x Ki 47	1.1	1.0	3.0	2.1	4	99	YOF
AC0-S_4-228 x Ki 47	1.1	1.0	3.2	2.3	2	99	OYFSF
AC0-S_4-159 x Ki 47	1.0	1.0	2.8	1.7	1	98	OYFSF
AC0-S_4-86 x Ki 47	1.0	1.0	3.2	1.9	1	97	OYF
AC0-S_4-136 x Ki 47	1.0	1.0	3.3	2.2	3	96	OYF
AC0-S_4-14 x Ki 47	1.1	1.0	3.2	1.9	1	97	OYF
AC0-S_4-57 x Ki 47	1.1	1.0	3.1	2.1	1	96	OYF
Mean	1.1	1.0	3.1	2.0	1	97	
Top 10 BC0 testcross hybrids							
BC0-S_4-90 x Ki 46	1.0	1.0	3.3	2.3	0	96	YOF
BC0-S_4-296 x Ki 46	1.1	1.0	3.1	2.0	2	96	OYF
BC0-S_4-250 x Ki 46	1.4	1.0	3.3	2.2	1	93	OYFSF
BC0-S_4-184 x Ki 46	1.0	1.0	3.1	2.0	1	100	OYF
BC0-S_4-71 x Ki 46	1.0	1.0	2.9	2.0	1	96	OYF
BC0-S_4-140 x Ki 46	1.4	1.0	2.9	2.2	2	94	OYF
BC0-S_4-115 x Ki 46	1.5	1.0	3.2	2.0	0	96	OYF
BC0-S_4-47 x Ki 46	1.1	1.0	3.2	2.4	0	98	OYF
BC0-S_4-186 x Ki 46	1.1	1.1	3.1	2.3	1	96	OYF
BC0-S_4-49 x Ki 46	1.0	1.0	3.2	2.4	2	95	OYF
Mean	1.2	1.0	3.1	2.2	1	96	

Appendix Table 2C (continued)

Entry	Seed. vigor	Husk cover	Aspect Plant	Aspect Ear	Rotten ears	Ears Plant^{-1}	Grain type
	(1-5)				%		
Top 10 C0 interpopulation hybrids							
AC0-S_4-159 x BC0-S_4-250	1.0	1.0	3.4	2.2	2	98	OYFSF
AC0-S_4-204 x BC0-S_4-47	1.1	1.1	3.3	2.1	0	98	OYFSF
AC0-S_4-159 x BC0-S_4-47	1.0	1.0	3.2	2.5	3	93	OYF
AC0-S_4-159 x BC0-S_4-296	1.1	1.0	3.0	2.2	2	99	OYF
AC0-S_4-159 x BC0-S_4-90	1.1	1.0	3.2	2.2	4	96	OYF
AC0-S_4-146 x BC0-S_4-184	1.1	1.0	3.1	2.4	5	94	OYFSF
AC0-S_4-159 x BC0-S_4-140	1.0	1.0	3.0	2.2	5	93	OYF
AC0-S_4-159 x BC0-S_4-184	1.0	1.0	3.0	2.3	1	94	OYFSF
AC0-S_4-4 x BC0-S_4-250	1.1	1.0	3.4	2.6	1	95	OYFSF
AC0-S_4-146 x BC0-S_4-296	1.1	1.0	3.1	1.9	1	100	OYFSF
Mean	1.1	1.0	3.2	2.3	2	96	
Hybrid checks							
KSX 4451	1.4	1.0	3.2	2.0	1	99	OYFSF
KSX 4453	1.0	1.0	3.1	2.1	2	99	YOF
BIG 949	1.3	1.1	2.9	2.1	1	99	OYF
PIONEER 30A30	1.3	1.0	3.1	2.4	3	100	OYFSF
KSX 4452 (Suwan 4452)	1.0	1.0	2.9	1.6	1	102	OYF
Suwan 3851 (Check)	1.0	1.3	3.3	2.3	0	99	YOFSF
Mean	1.1	1.1	3.1	2.1	1	100	
LSD 0.05	0.35	0.32	0.38	0.45	5.01	8.23	
LSD 0.01	0.46	0.42	0.50	0.60	6.62	10.87	

Appendix Table 3C Mean squares from analyses of variance of six traits of 100 C0 interpopulation hybrids from data combined over two locations in the 2002 late rainy season.

Source of variation	df		Seed. vigor	Husk cover	Aspect Plant	Aspect Ear	Rotten ears	Ears $Plant^{-1}$
			(1-5)				%	
Locations (L)	1		0.23	0.00	24.50	6.00	2118.71	1948.34
Replications/L	2		0.01	0.02	0.06	0.51	19.36	149.50
Varieties (V)	99		0.10	0.10	0.14	0.09	14.49	40.43
Females (A)		9	0.15	0.39 *	0.25	0.33	24.12	52.99
Males (B)		9	0.05	0.17	0.73	0.05	34.26	102.08
A x B		81	0.09 *	0.05	0.07 *	0.07	11.22	32.18
L x V	99		0.06	0.06	0.08	0.08	14.97	37.62
L x A		9	0.13 *	0.07	0.19 **	0.13 *	22.94 *	52.51
L x B		9	0.03	0.12 *	0.33 **	0.21 **	48.13 **	117.12 **
L x (AB)		81	0.06	0.05 **	0.04	0.06	10.41	27.13
Pooled error	198		0.07	0.02	0.06	0.06	11.89	25.05

*, ** Significant at the 0.05 and 0.01 probability levels, respectively.

Appendix Table 4C Estimates of components of genetic variances of six traits of 100 C0 interpopulation hybrids from data combined over two locations in the 2002 late rainy season.

Variance	Seed. vigor	Husk cover	Aspect Plant	Aspect Ear	Rotten ears	Ears $Plant^{-1}$
	(1-5)				%	
σ^2_f	0.00	0.01	0.00	0.01	0.32	0.52
σ^2_m	0.00	0.00	0.02	0.00	0.58	1.75
σ^2_{fm}	0.01	0.01	0.00	0.00	-0.17	1.78
σ^2_A	0.00	0.01	0.02	0.01	0.90	2.27
σ^2_D	0.01	0.01	0.00	0.00	-0.17	1.78
σ^2_D/σ^2_A	18.11	0.72	0.06	0.11	-0.19	0.79

Appendix Table 5C Estimates of gca and sca effects of six traits of 100 C0 interpopulation hybrids from data combined over two locations in the 2002 late rainy season.

Traits	Females†	Males‡										GCA effects of females
		B1	B2	B3	B4	B5	B6	B7	B8	B9	B10	
		SCA effects										
Seedling vigor (1-5)	A1	-0.01	0.04	-0.10	0.04	-0.08	-0.15	0.16	-0.05	-0.06	0.22	0.04
	A2	0.02	0.07	0.44 **	-0.05	-0.16	-0.24	-0.05	-0.14	-0.15	0.26 *	0.00
	A3	0.01	-0.06	-0.08	0.06	0.20	0.00	-0.06	-0.15	0.09	0.00	0.01
	A4	0.06	-0.14	-0.15	-0.14	-0.13	0.05	-0.01	0.15	0.39 *	-0.08	-0.04
	A5	0.01	0.06	0.17	0.06	-0.30 *	-0.13	-0.06	0.10	-0.04	0.12	0.14 **
	A6	0.06	-0.01	0.10	-0.01	0.00	0.05	-0.14	0.02	0.01	-0.08	-0.04
	A7	0.00	-0.08	-0.09	0.05	0.31 *	-0.01	-0.08	-0.04	-0.05	-0.01	-0.10 *
	A8	0.04	-0.04	-0.18	-0.04	-0.03	0.27 *	0.09	0.00	0.11	-0.23	-0.01
	A9	0.05	-0.03	-0.04	-0.03	0.24	-0.21	0.22	0.14	-0.13	-0.21	-0.02
	A10	-0.24	0.19	-0.08	0.06	-0.05	0.37 *	-0.06	-0.03	-0.16	0.00	0.01
	GCA effects of males	0.04	-0.01	0.00	-0.01	-0.02	0.05	-0.01	-0.05	-0.04	0.05	
	SE§ (gca effects)	0.04										
	SE (sca effects)	0.13										
Husk cover (1-5)	A1	-0.22 **	0.03	0.13	-0.29 **	0.51 **	-0.17 *	0.25 **	-0.05	-0.27 **	0.07	0.27 **
	A2	0.00	0.00	-0.03	0.05	-0.15 *	0.05	-0.04	0.03	0.07	0.03	-0.07 **
	A3	-0.03	-0.03	-0.05	0.02	-0.18 *	0.02	0.06	0.13	0.05	0.01	-0.05 *
	A4	0.13	0.01	-0.02	-0.07	0.23 **	-0.07	-0.03	-0.08	-0.04	-0.08	0.04
	A5	-0.04	-0.04	-0.07	0.01	0.06	0.13	-0.08	0.00	0.03	0.00	-0.03
	A6	-0.02	-0.02	-0.04	0.03	-0.04	0.03	-0.05	0.02	0.06	0.02	-0.06 *
	A7	-0.02	-0.02	0.08	0.03	-0.17 *	0.03	-0.05	0.02	0.06	0.02	-0.06 *
	A8	0.05	0.05	0.15 *	-0.03	0.02	-0.03	-0.12	-0.04	0.00	-0.04	0.00
	A9	0.07	0.07	-0.08	0.25 **	-0.20 *	0.00	-0.09	-0.02	0.02	-0.02	-0.02
	A10	0.07	-0.05	-0.08	0.00	-0.08	0.00	0.16 *	-0.02	0.02	-0.02	-0.02
	GCA effects of males	0.00	0.00	0.03	-0.05 *	0.15 **	-0.05 *	0.04	-0.03	-0.07 **	-0.03	
	SE (gca effects)	0.02										
	SE (sca effects)	0.07										

Appendix Table 5C (continued)

Traits	Females	Males B1	B2	B3	B4	B5	B6	B7	B8	B9	B10	GCA effects of females
		SCA effects										
Plant aspect (1-5)	A1	0.12	-0.26 *	0.13	-0.10	-0.10	0.23	-0.14	-0.01	0.03	0.10	-0.12 *
	A2	-0.12	0.13	-0.11	-0.09	-0.21	-0.01	0.13	0.13	0.17	-0.01	0.00
	A3	-0.05	0.08	-0.03	-0.01	0.12	-0.06	-0.05	0.08	-0.01	-0.06	0.05
	A4	-0.06	0.06	-0.05	-0.02	0.23	-0.07	0.06	-0.06	-0.15	0.05	0.06
	A5	0.10	-0.15	0.12	0.02	0.02	0.09	-0.15	-0.02	0.02	-0.04	0.15 **
	A6	-0.16	-0.04	0.10	0.13	0.13	0.08	-0.16	0.09	-0.12	-0.05	0.04
	A7	0.05	-0.07	0.07	0.09	0.09	-0.21	-0.07	0.05	0.09	-0.09	-0.05
	A8	0.08	0.08	-0.03	-0.14	-0.26 *	0.06	0.08	-0.05	0.12	0.06	-0.08
	A9	-0.06	-0.06	-0.17	-0.02	0.10	-0.07	0.19	0.19	-0.02	-0.07	-0.06
	A10	0.10	0.23	-0.01	0.14	-0.11	-0.04	0.10	-0.40 **	-0.11	0.09	0.02
	GCA effects of males	0.02	0.02	0.14 **	-0.02	0.11 *	-0.09 *	-0.10 *	-0.23 **	0.24 **	-0.09 *	
	SE (gca effects)	0.04										
	SE (sca effects)	0.12										
Ear aspect (1-5)	A1	-0.11	-0.06	0.03	-0.25	0.26 *	0.01	-0.06	0.14	0.04	-0.01	0.07
	A2	0.02	0.07	0.03	0.26 *	-0.25	-0.12	-0.18	0.14	-0.08	0.12	-0.06
	A3	-0.02	0.03	-0.01	-0.16	0.22	-0.16	0.16	-0.02	0.13	-0.17	0.11 *
	A4	-0.01	0.04	-0.12	0.23	-0.15	0.11	0.04	-0.13	-0.11	0.09	0.09 *
	A5	0.08	0.01	-0.03	0.07	-0.06	0.07	0.01	-0.17	-0.02	0.06	0.01
	A6	-0.02	0.16	-0.01	-0.03	-0.03	0.09	-0.09	0.11	0.00	-0.17	-0.14 **
	A7	0.02	0.19	0.03	-0.12	0.01	0.01	-0.06	0.02	-0.08	-0.01	-0.06
	A8	0.17	-0.28 *	0.06	-0.09	-0.09	0.03	0.09	-0.08	0.07	0.14	0.04
	A9	-0.16	-0.23	-0.02	0.08	0.08	0.08	0.14	0.22	-0.01	-0.18	-0.13 **
	A10	0.03	0.08	0.04	0.02	0.02	-0.11	-0.04	-0.22	0.05	0.13	0.06
	GCA effects of males	0.02	-0.03	0.01	0.03	0.03	0.03	-0.03	0.02	0.00	-0.08	
	SE (gca effects)	0.04										
	SE (sca effects)	0.13										

Appendix Table 5C (continued)

Traits	Females	Males										GCA effects of females
		B1	B2	B3	B4	B5	B6	B7	B8	B9	B10	
		SCA effects										
Rotten ears (%)	A1	-0.65	-1.00	4.04 *	-2.39	0.78	0.98	1.09	-0.19	-3.29	0.62	1.11 *
	A2	0.18	-0.63	-0.23	1.23	0.71	-0.19	-2.70	2.89	-0.41	-0.85	-0.52
	A3	-0.47	0.10	-1.59	0.72	2.21	-1.26	0.73	-0.42	-0.42	0.39	0.03
	A4	-3.14	-0.78	-0.83	1.03	1.01	0.73	1.91	-1.21	1.71	-0.43	0.21
	A5	-0.58	1.02	-0.28	0.35	1.24	2.71	0.27	-1.47	-2.08	-1.18	-0.81
	A6	-1.10	-0.04	0.76	1.18	-0.26	-2.07	-3.34	2.74	2.45	-0.32	-0.48
	A7	-0.65	2.51	-2.45	0.39	-0.83	0.69	0.58	-0.53	0.01	0.27	-0.44
	A8	3.03	-1.48	0.94	-0.43	-2.32	0.42	-1.15	-0.82	0.01	1.81	0.33
	A9	-0.13	0.30	0.11	-0.42	-1.15	-0.28	-0.33	2.04	-0.17	0.04	-0.84
	A10	3.51 *	0.00	-0.46	-1.66	-1.39	-1.75	2.94	-3.05	2.21	-0.35	1.41 *
	GCA effects of males	0.17	-1.61 *	0.13	1.06	-0.16	-0.21	1.74 **	-0.48	0.13	-0.77	
	SE (gca effects)	0.55										
	SE (sca effects)	1.72										
Ears plant^{-1} (%)	A1	2.15	0.24	-3.25	0.77	0.93	0.52	-0.82	-0.58	1.59	-1.56	-0.01
	A2	-4.29	-1.53	-1.78	1.97	-0.36	2.94	3.49	0.04	0.88	-1.35	-1.25
	A3	2.45	0.98	4.74	-2.66	-3.63	1.83	0.55	0.16	-5.40 *	0.97	-0.75
	A4	1.04	-0.94	-0.34	1.33	-1.37	-0.75	1.05	-0.06	-2.57	2.61	-1.19
	A5	0.15	-1.91	0.31	-1.10	-3.02	1.21	2.80	0.29	2.18	-0.90	1.72 *
	A6	2.48	1.58	2.89	-5.73 *	2.47	1.14	2.32	-1.64	-6.57 *	1.05	0.42
	A7	1.96	-3.67	1.29	0.49	1.26	-0.43	-1.68	-2.23	3.67	-0.65	0.87
	A8	1.01	-0.34	-6.48 *	1.36	1.09	-0.11	1.05	4.26	-0.89	-0.95	1.77 *
	A9	1.09	3.18	2.89	0.66	-0.57	-2.53	-5.81 *	-3.60	3.34	1.34	-0.56
	A10	-8.04 **	2.39	-0.27	2.92	3.20	-3.82	-2.95	3.36	3.77	-0.55	-1.03
	GCA effects of males	-0.90	1.17	-1.94 *	0.05	0.93	-0.89	-0.83	0.21	-1.37	3.57 **	
	SE (gca effects)	0.79										
	SE (sca effects)	2.50										

† A = AC0-S_4, ‡ B = BC0-S_4, § Standard error.

*, ** Exceeds its standard error by two and three times, respectively.

Appendix Table 6C Mean squares from analyses of variance of eight traits of C0 and C1 hybrids from data combined over two locations in the 2005 early rainy season.

Source of variation	df	Seed. vigor	Husk cover	Aspect: Plant	Aspect: Ear	Rotten ears	Ears $Plant^{-1}$	Corn borer	Leaf angle
		(1-5)				%		(1-5)	(°)
Locations (L)	1	0.54 **	0.92 **	9.96 **	0.41 **	2865.28 **	10.03	452.14 **	0.35
Treatments (T)	195	0.03 *	0.03 **	0.05 *	0.11 **	8.33	31.65 **	0.38	15.90 **
C0 hybrids	39	0.02	0.03	0.06 *	0.13 **	6.29	17.83 *	0.47	16.12 **
C0-S_3 TCHs†	19	0.02	0.03	0.05	0.18 **	5.41	17.93	0.34	16.54 **
AC0-S_3 TCHs	9	0.03	0.04	0.04	0.05	4.97	10.43	0.16	13.48 **
BC0-S_3 TCHs	9	0.01	0.00	0.07	0.22 **	6.13	27.36 *	0.35	6.02
AC0-S_3 TCHs vs. BC0-S_3 TCHs	1	0.01	0.13 *	0.01	1.05 **	2.92	0.52	1.90	138.86 **
C0-S_3 IPHs‡	9	0.02	0.03	0.06	0.06	7.29	17.93	0.25	21.07 **
C0-S_8 hybrids	9	0.01	0.03	0.11 **	0.11	6.93	19.52	0.75	12.21 **
C0-S_3 hybrids vs. C0-S_8 hybrids	1	0.02	0.06	0.04	0.05	14.39	2.13	2.57 *	2.82
C0-S_3 TCHs vs. C0-S_3 IPHs	1	0.12 *	0.04	0.00	0.03	0.29	15.78	0.06	11.94
C1 hybrids	149	0.03 **	0.03 **	0.05	0.10 **	9.13	29.21 **	0.33	15.55 **
C1-S_3 TCHs	49	0.03 *	0.02	0.04	0.13 **	9.33	10.51	0.39	15.78 **
AC1-S_3 TCHs	24	0.02	0.02 *	0.04	0.09	9.75	11.46	0.30	9.66 **
BC1-S_3 TCHs	24	0.04 *	0.01	0.03	0.14 **	9.31	9.74	0.24	12.69 **
AC1-S_3 TCHs vs. BC1-S_3 TCHs	1	0.00	0.05	0.33 **	0.87 **	0.00	6.43	6.02 **	236.93 **
C1-S_3 IPHs	99	0.03 **	0.03 **	0.05 *	0.09 *	8.93	38.71 **	0.29	15.36 **
C1-S_3 TCHs vs. C1-S_3 IPHs	1	0.03	0.03	0.06	0.17	19.51	5.42	0.93	22.66 *
Checks	5	0.06	0.09	0.06	0.05	2.64	166.01 **	0.64	8.11
C0 and C1 hybrids vs. Checks	1	0.14	0.04	0.01	0.20	5.44	284.39	1.60	108.22
C0 hybrids vs. C1 hybrids	1	0.00	0.11	0.23	0.16	0.14	10.00	2.22	5.67
T x L	195	0.02	0.02 *	0.04	0.06	7.96	11.78	0.38	4.04
C0 hybrids x L	39	0.02	0.03 **	0.04	0.05	7.36	10.01	0.47	3.34
C1 hybrids x L	149	0.02	0.01	0.04	0.06	8.35	12.50	0.33	4.23
Checks x L	5	0.03	0.02	0.06	0.09	2.32	7.03	0.64	2.80
(C0 and C1 hybrids vs. Checks) x L	1	0.06	0.00	0.00	0.41 *	7.97	8.26	1.60	1.65
(C0 hybrids vs. C1 hybrids) x L	1	0.06	0.13 **	0.03	0.10	1.12	1.09	2.22 *	11.73
Pooled error	338	0.04	0.01	0.05	0.08	7.33	27.65	0.46	5.67
CV (%)		13.00	12.31	6.66	12.98	81.19	3.53	29.70	6.14

† TCHs = testcross hybrids, ‡ IPHs = interpopulation hybrids.
*, ** Significant at the 0.05 and 0.01 probability levels, respectively.

Appendix Table 7C Means of eight traits, grain type and stalk and midrib color of the top 10 C0 and C1 hybrids of each group compared with Suwan 4452 (hybrid check) from data combined over two locations in the 2005 early rainy season.

Entry	Seed. vigor	Husk cover	Aspect Plant	Aspect Ear	Rotten ears	Ears $Plant^{-1}$	Grain type	Corn borer	Leaf angle	Color† Stalk	Color† Midrib
	(1-5)				%			(1-5)	(°)		
Top 10 C0 hybrids											
AC0-S_3-228 x Ki 47	1.1	1.3	3.1	1.8	7	95	OY^FSF	2.3	33.9	G	G
AC0-S_3-88 x Ki 47	1.0	1.0	2.9	1.7	3	100	OY^FSF	2.2	33.6	G	G
AC0-S_3-96 x Ki 47	1.0	1.3	3.0	1.5	5	93	OY^F	2.4	32.6	G	G
BC0-S_3-90 x Ki 46	1.1	1.0	2.8	2.1	5	91	OY^F	2.0	28.4	G	G
AC0-S_3-159 x BC0-S_3-47	1.3	1.3	3.1	1.8	4	93	OY^FSF	2.2	34.3	G	G
BC0-S_3-296 x Ki 46	1.1	1.1	3.0	1.9	5	98	OYF	1.7	31.7	G	G
AC0-S_3-180 x Ki 47	1.1	1.4	2.8	1.5	3	99	OY^F	2.4	33.4	G	G
AC0-S_3-159 x BC0-S_3-250	1.1	1.1	3.1	2.0	7	99	OY^F	2.1	36.7	G	G
AC0-S_3-72 x Ki 47	1.1	1.3	2.9	1.9	2	95	OY^FSF	2.6	32.9	G	G
AC0-S_3-204 x BC0-S_3-47	1.1	1.3	3.1	2.0	2	98	OY^FSF	2.4	36.8	G	G
Mean	1.1	1.2	3.0	1.8	4	96		2.2	33.4		
Top 10 C0 hybrids in S_8 generation											
AC0-S_8-159 x BC0-S_8-250	1.1	1.3	3.1	1.5	2	99	OY^FSF	3.0	34.2	G	G
AC0-S_8-72 x Ki 47	1.1	1.3	2.8	1.9	6	96	OY^FSF	1.6	34.2	G	G
BC0-S_8-296 x Ki 46	1.0	1.0	2.6	1.4	3	98	OYF	1.3	30.8	G	G
BC0-S_8-90 x Ki 46	1.1	1.0	3.0	2.3	0	98	OYF	2.9	27.6	G	G
AC0-S_4-88 x Ki 47	1.0	1.0	2.5	1.8	3	98	OYF	2.5	34.9	G	G
AC0-S_8-228 x Ki 47	1.1	1.3	3.0	1.8	5	97	OY^FSF	2.6	34.1	G	G
AC0-S_7-180 x Ki 47	1.1	1.3	3.1	1.9	3	97	OY^FSF	2.7	34.8	G	G
AC0-S_8-96 x Ki 47	1.3	1.3	3.1	1.7	3	100	OY^FSF	3.1	32.8	G	G
AC0-S_8-204 x BC0-S_8-47	1.0	1.3	3.1	1.8	0	99	OY^FSF	2.4	29.9	G	G
AC0-S_8-159 x BC0-S_8-47	1.0	1.0	3.1	1.9	3	89	OY^FSF	3.1	34.2	G	G
Mean	1.1	1.2	3.0	1.8	3	97		2.5	32.8		
Top 10 C1 hybrids											
AC1-S_3-86-1 x Ki 47	1.1	1.0	2.8	1.5	5	100	OY^F	1.8	34.2	G	G
BC1-S_3-186-16 x Ki 46	1.0	1.0	2.6	2.2	3	98	OY^F	1.7	27.8	G	G
AC1-S_3-86-10 x BC1-S_3-222-20	1.1	1.1	2.9	1.4	4	98	OY^FSF	2.1	33.0	G	G
BC1-S_3-71-22 x Ki 46	1.1	1.0	2.6	1.9	6	94	OYF	1.5	33.3	G	G
AC1-S_3-175-13 x Ki 47	1.1	1.0	2.6	1.7	4	101	OY^FSF	2.4	34.9	G	G
AC1-S_3-180-2 x Ki 47	1.0	1.3	2.8	1.6	6	96	OY^FSF	2.3	30.8	G	G
BC1-S_3-184-16 x Ki 46	1.1	1.0	2.9	1.9	4	98	OYF	1.8	31.0	G	G
BC1-S_3-71-1 x Ki 46	1.0	1.0	2.6	1.9	1	100	OYF	1.7	30.6	G	G
AC1-S_3-175-13 x BC1-S_3-90-7	1.4	1.0	2.6	1.6	2	97	OY^F	2.4	36.2	G	G
AC1-S_2-57-12 x BC1-S_3-222-20	1.1	1.0	2.9	1.7	5	94	OY^FSF	1.8	38.1	G	G
Mean	1.1	1.0	2.7	1.7	4	98		2.0	33.0		

Appendix Table 7C (continued)

Entry	Seed. vigor	Husk cover	Aspect Plant	Aspect Ear	Rotten ears	Ears Plant^{-1}	Grain type	Corn borer	Leaf angle	Color Stalk	Color Midrib
	(1-5)	(1-5)	(1-5)	(1-5)	%	%		(1-5)	(°)		
Top 10 AC0 testcross hybrids											
AC0-S_3-86 x Ki 47	1.0	1.0	2.9	1.6	3	97	OYF	2.2	37.0	G	G
AC0-S_3-228 x Ki 47	1.1	1.3	3.1	1.8	7	95	OY^FSF	2.3	33.9	G	G
AC0-S_3-88 x Ki 47	1.0	1.0	2.9	1.7	3	100	OY^FSF	2.2	33.6	G	G
AC0-S_3-96 x Ki 47	1.0	1.3	3.0	1.5	5	93	OY^F	2.4	32.6	G	G
AC0-S_3-136 x Ki 47	1.4	1.0	3.0	1.6	4	99	OYF	2.1	34.5	G	G
AC0-S_3-159 x Ki 47	1.0	1.0	2.9	1.9	5	96	OY^FSF	2.1	40.7	G	G
AC0-S_3-180 x Ki 47	1.1	1.4	2.8	1.5	3	99	OY^F	2.4	33.4	G	G
AC0-S_3-57 x Ki 47	1.0	1.0	2.8	1.8	2	98	OYF	1.8	36.3	G	G
AC0-S_3-72 x Ki 47	1.1	1.3	2.9	1.9	2	95	OY^FSF	2.6	32.9	G	G
AC0-S_3-14 x Ki 47	1.0	1.1	3.1	1.5	4	97	OYF	2.9	32.3	G	G
Mean	1.1	1.1	2.9	1.7	4	97		2.3	34.7		
Top 10 AC1 testcross hybrids											
AC1-S_3-86-1 x Ki 47	1.1	1.0	2.8	1.5	5	100	OY^F	1.8	34.2	G	G
AC1-S_3-175-13 x Ki 47	1.1	1.0	2.6	1.7	4	101	OY^FSF	2.4	34.9	G	G
AC1-S_3-180-2 x Ki 47	1.0	1.3	2.8	1.6	6	96	OY^FSF	2.3	30.8	G	G
AC1-S_3-86-10 x Ki 47	1.1	1.0	2.8	1.6	3	97	OY^FSF	1.6	34.1	G	G
AC1-S_2-245-17 x Ki 47	1.0	1.0	2.9	2.0	3	100	OYF	2.0	34.1	G	G
AC1-S_3-228-13 x Ki 47	1.0	1.0	3.1	1.8	1	99	OY^FSF	2.5	33.6	G	G
AC1-S_3-88-13 x Ki 47	1.1	1.0	2.8	1.6	3	97	OY^F	1.7	34.7	G	G
AC1-S_2-204-14 x Ki 47	1.1	1.3	2.8	2.1	3	100	OY^F	1.4	38.0	G	G
AC1-S_2-228-3 x Ki 47	1.4	1.1	3.0	1.8	1	97	OY^FSF	2.1	35.4	G	G
AC1-S_2-57-12 x Ki 47	1.0	1.0	2.8	1.8	2	99	OY^FSF	2.4	33.2	G	G
Mean	1.1	1.1	2.8	1.7	3	98		2.0	34.3		
Top 10 BC0 testcross hybrids											
BC0-S_3-140 x Ki 46	1.1	1.0	3.0	2.1	3	100	OY^F	2.2	31.7	G	G
BC0-S_3-90 x Ki 46	1.1	1.0	2.8	2.1	5	91	OY^F	2.0	28.4	G	G
BC0-S_3-184 x Ki 46	1.1	1.0	2.8	1.8	1	100	OYF	1.6	28.7	G	G
BC0-S_3-71 x Ki 46	1.1	1.0	2.5	2.0	1	95	OYF	1.3	29.2	G	G
BC0-S_3-47 x Ki 46	1.0	1.0	3.1	2.0	2	97	OY^FSF	2.4	30.7	G	G
BC0-S_3-115 x Ki 46	1.0	1.0	2.9	1.2	3	103	OYF	1.2	33.7	G	G
BC0-S_3-296 x Ki 46	1.1	1.1	3.0	1.9	5	98	OYF	1.7	31.7	G	G
BC0-S_3-49 x Ki 46	1.1	1.0	3.0	2.3	6	94	OY^F	1.6	31.6	G	G
BC0-S_3-250 x Ki 46	1.1	1.0	3.0	2.3	3	93	OYF	2.3	32.7	G	G
BC0-S_3-186 x Ki 46	1.3	1.0	2.9	2.4	4	99	OYF	2.3	31.8	G	G
Mean	1.1	1.0	2.9	2.0	3	97		1.9	31.0		
Top 10 BC1 testcross hybrids											
BC1-S_3-186-16 x Ki 46	1.0	1.0	2.6	2.2	3	98	OY^F	1.7	27.8	G	G
BC1-S_3-71-22 x Ki 46	1.1	1.0	2.6	1.9	6	94	OYF	1.5	33.3	G	G
BC1-S_3-184-16 x Ki 46	1.1	1.0	2.9	1.9	4	98	OYF	1.8	31.0	G	G
BC1-S_3-71-1 x Ki 46	1.0	1.0	2.6	1.9	1	100	OYF	1.7	30.6	G	G
BC1-S_3-47-9 x Ki 46	1.1	1.0	3.0	2.2	1	97	OYF	1.3	28.9	G	G
BC1-S_3-246-11 x Ki 46	1.0	1.0	2.9	1.7	4	100	OY^FSF	1.1	33.2	G	G
BC1-S_3-90-2 x Ki 46	1.3	1.0	2.8	2.2	4	97	OYF	1.9	29.2	G	G
BC1-S_3-186-3 x Ki 46	1.0	1.0	2.6	2.4	3	100	OYF	2.1	29.5	G	G
BC1-S_3-90-7 x Ki 46	1.0	1.0	2.8	1.4	6	99	OYF	1.8	29.2	G	G
BC1-S_3-296-2 x Ki 46	1.0	1.0	2.8	2.0	1	98	OYF	1.7	31.0	G	G
Mean	1.1	1.0	2.8	2.0	3	98		1.7	30.4		

Appendix Table 7C (continued)

Entry	Seed. vigor	Husk cover	Aspect Plant	Aspect Ear	Rotten ears	Ears Plant^{-1}	Grain type	Corn borer	Leaf angle	Color Stalk	Color Midrib
	(1-5)				%			(1-5)	(°)		
Top 10 C0 interpopulation hybrids											
AC0-S_3-159 x BC0-S_3-90	1.3	1.0	2.8	2.0	2	97	OY^FSF	2.7	32.6	G	G
AC0-S_3-146 x BC0-S_3-184	1.3	1.1	2.8	1.7	4	98	OYF	1.8	28.0	G	G
AC0-S_3-159 x BC0-S_3-47	1.3	1.3	3.1	1.8	4	93	OY^FSF	2.2	34.3	G	G
AC0-S_3-159 x BC0-S_3-140	1.1	1.1	2.8	2.1	3	94	OYF	2.1	34.9	G	G
AC0-S_3-159 x BC0-S_3-184	1.3	1.0	2.9	2.2	1	99	OYF	2.4	35.5	G	G
AC0-S_3-146 x BC0-S_3-296	1.3	1.0	2.8	1.9	4	97	OYF	1.5	31.0	G	G
AC0-S_3-159 x BC0-S_3-250	1.1	1.1	3.1	2.0	7	99	OY^F	2.1	36.7	G	G
AC0-S_3-159 x BC0-S_3-296	1.0	1.0	2.8	1.8	4	92	OYF	1.9	38.1	G	G
AC0-S_3-204 x BC0-S_3-47	1.1	1.3	3.1	2.0	2	98	OY^FSF	2.4	36.8	G	G
AC0-S_3-4 x BC0-S_3-250	1.3	1.4	2.9	1.6	7	91	OYF	2.4	30.3	G	G
Mean	1.2	1.1	2.9	1.9	4	96		2.2	33.8		
Top 10 C1 interpopulation hybrids											
AC1-S_3-86-10 x BC1-S_3-222-20	1.1	1.1	2.9	1.4	4	98	OY^FSF	2.1	33.0	G	G
AC1-S_3-175-13 x BC1-S_3-90-7	1.4	1.0	2.6	1.6	2	97	OY^F	2.4	36.2	G	G
AC1-S_2-57-12 x BC1-S_3-222-20	1.1	1.0	2.9	1.7	5	94	OY^FSF	1.8	38.1	G	G
AC1-S_3-180-2 x BC1-S_3-222-20	1.3	1.0	3.0	1.6	6	99	OY^F	2.5	32.5	G	G
AC1-S_2-57-12 x BC1-S_3-186-16	1.0	1.0	2.9	1.7	2	99	OY^FSF	2.8	31.0	G	G
AC1-S_2-204-14 x BC1-S_3-222-20	1.1	1.1	3.1	1.5	4	104	OYF	2.1	36.9	G	G
AC1-S_3-21-2 x BC1-S_3-71-1	1.3	1.0	2.8	1.8	3	101	OY^F	2.5	32.3	G	G
AC1-S_2-204-14 x BC1-S_3-186-16	1.0	1.0	2.9	1.5	1	96	OYF	2.2	31.2	G	G
AC1-S_3-175-13 x BC1-S_3-186-16	1.4	1.0	2.8	1.9	4	97	OY^F	2.1	36.2	G	G
AC1-S_3-21-9 x BC1-S_3-71-1	1.0	1.0	2.4	1.6	3	104	OYF	1.8	27.7	G	G
Mean	1.2	1.0	2.8	1.6	3	99		2.2	33.5		
Hybrid checks											
NK 40	1.3	1.0	2.6	1.5	3	99	OY^FSF	1.6	29.4	G	G
PAC 999	1.3	1.3	2.9	1.8	2	98	OY^FSF	3.1	30.1	G	G
BIG 919	1.1	1.5	3.0	1.9	4	96	OY^FSF	2.1	29.1	G	G
DK 888	1.5	1.0	2.9	1.8	4	120	OY^FSF	2.6	33.4	G	G
KSX 4601	1.0	1.0	3.0	1.9	1	102	OY^F	3.0	27.2	G	G
Suwan 4452 (Check)	1.3	1.0	2.6	1.6	3	97	OYF	2.2	29.5	G	G
Mean	1.2	1.1	2.8	1.8	3	102		2.4	29.8		
LSD 0.05	0.29	0.26	0.38	0.48	5.56	6.77		1.21	3.97		
LSD 0.01	0.38	0.34	0.50	0.64	7.34	8.93		1.60	5.23		

† G = green.

Appendix Table 8C Means of 18 traits, grain type and colors of stalk and midrib of other high-yielding C1 hybrids with not significantly different from Suwan 4452 (hybrid check) from data combined over two locations in the 2005 early rainy season.

Entry	Grain yield at 15% moist.	Relat. to check	Seed. vigor	Days to 50% Ant.	Days to 50% Silk.	Height Plant	Height Ear	Lodging Stalk	Lodging Root	Foliar dis.	Husk cover	Aspect Plant	Aspect Ear	Rotten ears	Ears $Plant^{-1}$	Grain moist.	Grain shell.	Grain type	Corn borer	Leaf angle	Color† Stalk	Color† Midrib
	kg ha^{-1}	%	(1-5)	d		cm		%	(1-5)					%					(1-5)	(°)		
Other 10 high-yielding AC1 testcross hybrids																						
AC1-S_2-228-8 x Ki 47	7,936	93	1.3	50	51	253	145	4	2.1	2.9	1.0	2.9	1.9	6	98	21.85	83.15	OYF	2.5	36.4	G	G
AC1-S_3-146-17 x Ki 47	7,896	92	1.1	51	51	252	143	12	2.2	3.0	1.3	3.1	1.6	5	98	19.83	83.31	OY^FSF	2.7	31.6	G	G
AC1-S_3-88-15 x Ki 47	7,826	91	1.3	50	51	258	154	3	2.0	2.8	1.0	2.8	1.6	1	98	20.26	84.28	OYF	3.1	37.8	G	G
AC1-S_3-159-19 x Ki 47	7,825	91	1.3	51	51	239	140	8	2.7	2.9	1.0	2.9	2.1	4	99	20.80	85.19	OY^FSF	2.6	34.1	G	G
AC1-S_3-72-17 x Ki 47	7,674	89	1.0	50	51	248	145	2	2.7	2.9	1.0	2.9	1.6	4	97	20.31	81.27	OY^FSF	1.8	33.2	G	G
AC1-S_3-83-18 x Ki 47	7,521	88	1.3	50	51	241	145	2	2.4	2.9	1.3	2.9	1.9	4	94	21.14	84.28	OY^FSF	2.2	36.1	G	G
AC1-S_3-204-6 x Ki 47	7,428	87	1.0	51	51	246	144	2	1.9	2.9	1.3	2.9	1.9	2	99	19.01	84.54	OY^F	2.1	35.2	G	G
AC1-S_2-245-20 x Ki 47	7,369	86	1.1	50	51	245	150	2	1.7	3.1	1.1	3.1	2.0	4	100	19.01	81.24	OYF	2.2	31.9	G	G
AC1-S_3-72-5 x Ki 47	7,262	85	1.0	49	50	240	144	2	2.0	3.0	1.3	3.0	1.9	2	101	20.59	81.48	OY^FSF	2.4	37.1	G	G
AC1-S_3-55-9 x Ki 47	7,243	84	1.0	51	53	254	143	7	3.0	2.8	1.0	3.0	2.1	7	98	20.40	84.59	OY^F	2.4	38.1	G	G
Mean	7,598	89	1.1	50	51	248	145	4	2.3	2.9	1.1	2.9	1.8	4	98	20.32	83.33		2.4	35.1		
Other 15 high-yielding BC1 testcross hybrids																						
BC1-S_3-32-19 x Ki 46	7,926	92	1.0	52	52	236	139	4	2.0	2.6	1.0	2.6	1.7	1	94	21.67	77.77	OYF	1.3	33.5	G	G
BC1-S_3-37-6 x Ki 46	7,895	92	1.1	50	51	245	143	2	1.9	2.9	1.1	2.9	2.2	5	98	19.25	83.02	OYF	1.7	28.4	G	G
BC1-S_2-280-3 x Ki 46	7,841	91	1.3	50	51	236	131	3	2.6	2.9	1.0	2.9	2.2	1	95	19.94	79.94	OYF	1.8	30.3	G	G
BC1-S_3-184-9 x Ki 46	7,838	91	1.0	51	52	226	134	1	2.0	2.6	1.0	2.6	2.1	3	99	18.95	83.22	OYF	1.8	30.7	G	G
BC1-S_3-222-20 x Ki 46	7,825	91	1.0	51	52	244	151	3	2.3	2.8	1.0	2.8	1.8	3	96	21.04	81.57	OYF	1.3	35.6	G	G
BC1-S_3-32-20 x Ki 46	7,664	89	1.0	48	49	219	118	1	1.9	2.9	1.1	2.9	2.2	1	98	18.76	83.81	OYF	2.5	30.8	G	G
BC1-S_3-115-9 x Ki 46	7,622	89	1.0	50	50	240	127	2	2.0	2.8	1.0	2.8	1.8	5	100	19.85	81.68	OYF	2.1	34.7	G	G
BC1-S_3-90-12 x Ki 46	7,610	89	1.0	51	52	238	134	1	2.0	2.8	1.0	2.8	2.3	9	94	20.12	81.03	OYF	1.0	28.2	G	G
BC1-S_3-296-19 x Ki 46	7,571	88	1.1	51	51	233	133	3	2.0	2.9	1.0	2.9	2.1	8	93	20.70	83.10	OY^F	1.7	33.7	G	G
BC1-S_3-186-20 x Ki 46	7,539	88	1.0	50	51	229	125	1	2.0	2.8	1.4	2.8	1.7	5	97	19.68	83.01	OYF	1.6	32.9	G	G
BC1-S_3-115-7 x Ki 46	7,503	87	1.4	50	52	252	153	4	2.5	2.9	1.0	2.9	1.5	4	98	21.49	79.35	OYF	1.6	35.1	G	G
BC1-S_3-184-4 x Ki 46	7,399	86	1.0	50	50	237	143	3	3.2	2.8	1.0	2.8	2.1	4	97	21.17	84.56	OYF	1.9	36.2	G	G
BC1-S_3-172-19 x Ki 46	7,364	86	1.3	50	50	230	129	2	2.2	2.8	1.0	2.8	2.3	5	96	19.03	83.69	OY^F	1.7	30.2	G	G
BC1-S_3-115-6 x Ki 46	7,337	86	1.5	50	51	245	139	1	2.3	2.8	1.0	2.8	2.2	3	93	22.10	80.07	OYF	2.2	35.0	G	G
BC1-S_3-115-19 x Ki 46	7,251	85	1.3	51	51	237	136	2	2.3	3.0	1.0	3.0	2.4	6	100	19.75	80.47	OYF	1.8	31.7	G	G
Mean	7,612	89	1.1	50	51	237	136	2	2.2	2.8	1.0	2.8	2.0	4	96	20.23	81.75		1.7	32.5		

Appendix Table 8C (continued)

Entry	Grain yield at 15% moist.	Relat. to check	Seed. vigor	Days to 50% Ant.	Days to 50% Silk.	Height Plant	Height Ear	Lodging Stalk	Lodging Root	Foliar dis.	Husk cover	Aspect Plant	Aspect Ear	Rotten ears	Ears Plant^{-1}	Grain moist.	Grain shell.	Grain type	Corn borer	Leaf angle	Color Stalk	Color Midrib
	kg ha^{-1}	%	(1-5)	d		cm		%	(1-5)					%					(1-5)	(°)		
Other 65 high-yielding C1 interpopulation hybrids																						
AC1-S_3-72-17 x BC1-S_3-71-1	8,242	96	1.0	50	51	239	138	1	2.2	2.6	1.4	2.6	1.4	4	98	20.64	80.65	OY^FSF	2.0	29.3	G	G
AC1-S_3-72-17 x BC1-S_3-47-9	8,197	96	1.1	49	51	236	123	2	2.5	2.8	1.3	2.8	1.7	1	101	18.87	82.63	OY^FSF	1.7	29.3	G	G
AC1-S_3-86-10 x BC1-S_3-47-9	8,190	95	1.1	50	53	247	128	0	2.9	2.9	1.0	2.9	1.8	2	98	20.61	82.90	OY^FSF	1.2	29.9	G	G
AC1-S_3-72-17 x BC1-S_3-222-20	8,179	95	1.0	52	53	248	149	5	2.1	2.5	1.0	2.5	1.8	3	96	19.84	84.91	OY^F	1.3	32.2	G	G
BC1-S_3-222-20 x AC1-S_3-57-4	8,160	95	1.0	53	54	253	152	5	2.1	2.8	1.1	2.9	1.7	2	98	20.69	81.83	OYF	1.1	35.5	G	G
AC1-S_3-175-13 x BC1-S_3-222-20	8,145	95	1.3	53	54	247	154	3	2.3	2.8	1.0	2.8	1.8	4	99	20.37	86.58	OY^F	2.1	38.2	G	G
AC1-S_3-175-13 x BC1-S_3-246-11	8,125	95	1.1	52	52	251	153	2	2.6	2.4	1.0	2.4	1.9	3	94	21.40	82.18	OY^FSF	1.5	36.9	G	G
AC1-S_2-204-14 x BC1-S_3-71-1	8,111	95	1.0	51	52	242	139	2	2.3	2.8	1.4	2.8	1.9	2	98	19.80	81.26	OYF	2.4	30.9	G	G
AC1-S_2-57-12 x BC1-S_3-115-9	8,094	94	1.0	52	52	255	150	2	2.0	3.0	1.0	3.0	1.6	2	98	20.72	81.98	OY^FSF	1.8	36.1	G	G
AC1-S_3-175-13 x BC1-S_3-184-16	8,049	94	1.3	52	51	253	144	5	2.8	2.8	1.0	2.8	1.9	5	96	21.59	84.18	OY^FSF	2.1	37.9	G	G
AC1-S_3-72-17 x BC1-S_3-90-7	8,037	94	1.0	50	52	243	138	9	2.5	2.8	1.3	2.9	1.5	3	98	20.98	79.17	OYF	1.7	29.6	G	G
AC1-S_3-86-10 x BC1-S_3-186-3	8,020	94	1.0	50	52	255	139	3	3.2	2.9	1.0	3.0	2.0	1	95	21.59	85.35	OY^FSF	1.7	32.2	G	G
AC1-S_3-21-9 x BC1-S_3-186-16	8,016	93	1.0	52	54	273	153	4	3.0	2.8	1.0	2.8	1.7	6	96	20.94	82.13	OYF	1.5	27.0	G	G
AC1-S_2-57-12 x BC1-S_3-71-1	8,009	93	1.0	52	53	252	145	1	2.2	2.8	1.4	2.8	1.8	1	97	21.88	81.35	OYF	2.6	28.8	G	G
AC1-S_3-180-2 x BC1-S_3-184-16	8,001	93	1.1	50	51	243	136	2	2.5	3.1	1.3	3.1	2.0	5	98	19.25	86.18	OY^F	2.2	28.1	G	G
AC1-S_2-57-12 x BC1-S_3-246-11	7,996	93	1.0	52	52	253	148	5	2.6	2.9	1.0	2.9	2.0	1	98	20.17	82.60	OY^F	2.3	33.3	G	G
AC1-S_3-180-2 x BC1-S_3-186-16	7,988	93	1.1	52	54	255	145	5	3.1	2.9	1.1	2.9	1.9	5	99	20.36	81.80	OY^FSF	2.4	26.4	G	G
AC1-S_2-204-14 x BC1-S_3-115-9	7,967	93	1.0	51	51	261	148	2	2.5	2.9	1.3	2.9	1.6	2	102	20.40	82.91	OYF	2.1	33.2	G	G
AC1-S_3-180-2 x BC1-S_3-90-7	7,967	93	1.3	52	52	256	154	5	2.7	3.0	1.3	3.0	1.5	4	94	20.25	80.72	OY^F	2.5	28.2	G	G
AC1-S_2-204-14 x BC1-S_3-90-7	7,944	93	1.0	51	52	254	149	8	2.6	2.8	1.3	2.8	1.7	4	102	20.96	81.35	OYF	2.6	32.5	G	G
AC1-S_3-72-17 x BC1-S_3-186-16	7,941	93	1.1	50	52	249	136	1	3.0	2.9	1.0	2.9	1.7	3	97	20.30	82.44	OY^FSF	2.5	28.4	G	G
AC1-S_3-180-2 x BC1-S_3-246-11	7,927	92	1.1	51	51	248	150	2	2.7	3.0	1.0	3.0	2.0	4	99	19.32	83.23	OY^FSF	2.4	30.5	G	G
AC1-S_2-228-8 x BC1-S_3-222-20	7,921	92	1.1	53	53	264	159	10	2.5	2.9	1.0	2.9	1.6	3	93	20.37	82.42	OY^FSF	1.7	37.5	G	G
AC1-S_2-204-14 x BC1-S_3-246-11	7,889	92	1.0	49	50	254	154	4	2.4	2.8	1.1	2.8	2.0	4	102	20.77	82.84	OY^F	2.6	36.1	G	G
AC1-S_2-57-12 x BC1-S_3-90-7	7,870	92	1.1	51	52	259	154	3	2.2	2.9	1.0	2.9	1.6	1	94	20.18	81.71	OYF	2.3	34.3	G	G

Appendix Table 8C (continued)

Entry	Grain yield at 15% moist.	Relat. to check	Seed. vigor	Days to 50% Ant.	Days to 50% Silk.	Height Plant	Height Ear	Lodging Stalk	Lodging Root	Foliar dis.	Husk cover	Aspect Plant	Aspect Ear	Rotten ears	Ears $Plant^{-1}$	Grain moist.	Grain shell.	Grain type	Corn borer	Leaf angle	Color Stalk	Color Midrib
	$kg\ ha^{-1}$	%	(1-5)	d		cm		%	(1-5)					%					(1-5)	(°)		
Other 65 high-yielding C1 interpopulation hybrids (continued)																						
AC1-S_2-57-12 x BC1-S_3-186-3	7,857	92	1.1	51	52	255	145	1	2.3	2.9	1.0	2.9	1.9	0	100	20.67	84.87	OY^F	2.1	33.9	G	G
AC1-S_2-228-8 x BC1-S_3-47-9	7,812	91	1.1	49	51	248	132	3	2.2	3.0	1.1	3.0	1.8	4	101	20.30	80.12	OY^FSF	1.8	32.4	G	G
AC1-S_3-180-2 x BC1-S_3-47-9	7,800	91	1.3	49	51	229	127	2	2.6	3.1	1.1	3.3	2.2	1	99	18.81	83.24	OY^FSF	1.9	24.5	G	G
AC1-S_2-204-14 x BC1-S_3-47-9	7,779	91	1.1	49	51	248	132	11	2.5	2.9	1.3	3.0	2.3	1	101	19.42	83.07	OY^FSF	2.2	32.5	G	G
AC1-S_3-86-10 x BC1-S_3-32-19	7,747	90	1.0	52	54	247	135	1	2.1	2.8	1.0	2.8	1.8	3	102	22.00	80.09	OYF	2.0	32.0	G	G
AC1-S_3-21-9 x BC1-S_3-47-9	7,726	90	1.3	50	52	249	130	4	2.7	2.8	1.0	2.9	1.9	2	97	19.28	82.02	OYF	1.3	31.9	G	G
AC1-S_3-21-2 x BC1-S_3-222-20	7,708	90	1.5	53	54	252	150	2	2.4	2.8	1.0	2.8	1.7	3	93	18.85	85.03	OYF	1.9	36.8	G	G
AC1-S_3-175-13 x BC1-S_3-115-9	7,691	90	1.4	52	51	238	134	1	2.4	2.9	1.1	2.9	2.0	3	100	19.69	83.79	OYF	2.2	39.7	G	G
BC1-S_3-246-11 x AC1-S_3-57-4	7,668	89	1.3	52	53	254	153	3	2.5	2.9	1.0	2.9	2.0	3	97	21.34	78.82	OY^FSF	1.3	35.4	G	G
AC1-S_2-204-14 x BC1-S_3-184-16	7,664	89	1.1	51	52	259	144	1	2.2	2.8	1.6	2.8	2.1	4	98	20.82	83.75	OYF	2.3	32.0	G	G
AC1-S_3-180-2 x BC1-S_3-71-1	7,658	89	1.1	51	52	234	139	2	2.0	2.9	1.1	2.9	1.9	1	100	20.14	80.31	OY^FSF	2.6	27.9	G	G
AC1-S_2-57-12 x BC1-S_3-184-16	7,639	89	1.0	52	53	257	143	1	2.3	2.9	1.0	2.9	2.1	1	98	20.44	83.14	OYF	2.0	32.7	G	G
AC1-S_3-86-10 x BC1-S_3-71-1	7,635	89	1.1	51	52	253	136	0	2.2	2.8	1.0	2.8	1.8	3	100	20.55	80.54	OY^FSF	2.0	32.4	G	G
AC1-S_3-180-2 x BC1-S_3-186-3	7,624	89	1.1	50	51	249	149	1	2.8	3.1	1.0	3.1	2.2	2	101	18.76	83.01	OY^F	1.7	28.8	G	G
AC1-S_3-86-10 x BC1-S_3-90-7	7,617	89	1.0	51	52	250	141	4	2.7	2.8	1.0	2.9	1.7	1	97	21.77	82.30	OY^F	1.7	34.0	G	G
AC1-S_3-86-10 x BC1-S_3-184-16	7,613	89	1.0	51	53	257	139	-1	2.0	2.9	1.1	2.9	2.1	3	101	22.58	83.27	OY^FSF	2.4	33.4	G	G
AC1-S_3-175-13 x BC1-S_3-47-9	7,580	88	1.0	50	51	231	129	1	2.4	2.9	1.1	2.9	1.9	1	99	20.09	82.40	OY^FSF	2.4	34.0	G	G
AC1-S_3-175-13 x BC1-S_3-32-19	7,579	88	1.1	52	52	247	145	3	2.0	2.8	1.3	2.8	1.9	2	97	21.31	80.88	OYF	2.2	36.5	G	G
AC1-S_3-21-2 x BC1-S_3-186-16	7,578	88	1.1	52	53	261	145	5	2.5	2.9	1.0	2.9	2.0	4	97	20.29	84.75	OY^F	2.0	32.6	G	G
AC1-S_2-57-12 x BC1-S_3-47-9	7,575	88	1.0	50	52	247	133	2	2.6	3.0	1.0	3.0	2.0	2	99	20.04	82.15	OY^FSF	1.9	33.7	G	G
AC1-S_2-204-14 x BC1-S_3-186-3	7,541	88	1.1	49	50	244	133	3	2.4	2.9	1.0	2.9	1.9	1	104	19.91	82.23	OY^F	2.3	31.8	G	G
AC1-S_3-21-9 x BC1-S_3-246-11	7,486	87	1.3	51	53	257	154	1	2.7	2.8	1.0	2.8	2.1	5	95	22.15	81.81	OYF	1.6	30.6	G	G
AC1-S_3-72-17 x BC1-S_3-186-3	7,462	87	1.0	49	51	240	139	5	2.6	2.8	1.0	3.0	2.0	3	100	20.27	85.55	OY^F	1.5	31.1	G	G
AC1-S_3-180-2 x BC1-S_3-32-19	7,454	87	1.1	52	53	244	142	4	2.1	3.0	1.0	3.0	2.1	2	99	19.81	81.26	OYF	2.2	31.3	G	G
BC1-S_3-71-1 x AC1-S_3-57-4	7,430	87	1.1	52	53	246	142	3	2.0	2.8	1.1	2.8	1.7	1	97	22.43	81.05	OY^F	1.9	30.2	G	G

Appendix Table 8C (continued)

Entry	Grain yield at 15% moist.	Relat. to check	Seed. vigor	Days to 50% Ant.	Days to 50% Silk.	Height Plant	Height Ear	Lodging Stalk	Lodging Root	Foliar dis.	Husk cover	Aspect Plant	Aspect Ear	Rotten ears	Ears $Plant^{-1}$	Grain moist.	Grain shell.	Grain type	Corn borer	Leaf angle	Color Stalk	Color Midrib
	kg ha^{-1}	%	(1-5)	d		cm		%		(1-5)				%					(1-5)	(°)		
Other 65 high-yielding C1 interpopulation hybrids (continued)																						
AC1-S_2-228-8 x BC1-S_3-186-3	7,416	86	1.3	51	52	250	145	1	2.2	2.9	1.0	2.9	2.0	2	98	20.98	83.93	OY^F	2.0	31.8	G	G
AC1-S_2-57-12 x BC1-S_3-32-19	7,387	86	1.0	51	52	252	149	5	2.2	2.9	1.0	2.9	1.9	2	97	20.99	79.31	OYF	2.0	33.2	G	G
AC1-S_2-228-8 x BC1-S_3-90-7	7,384	86	1.3	52	53	256	152	8	2.5	3.0	1.0	3.0	1.4	5	90	21.91	80.43	OYF	1.8	33.3	G	G
AC1-S_2-228-8 x BC1-S_3-71-1	7,382	86	1.0	51	52	251	145	3	2.2	3.0	1.1	3.0	1.9	4	98	22.70	78.39	OY^F	2.3	32.5	G	G
AC1-S_3-72-17 x BC1-S_3-246-11	7,374	86	1.0	50	52	247	146	4	2.5	2.6	1.0	2.8	2.1	3	96	20.65	81.25	OY^FSF	1.7	32.5	G	G
AC1-S_3-21-9 x BC1-S_3-222-20	7,355	86	1.0	52	54	260	155	7	2.5	2.8	1.0	2.8	1.9	3	95	19.35	83.69	OY^F	2.4	32.4	G	G
AC1-S_2-228-8 x BC1-S_3-246-11	7,349	86	1.1	52	52	260	152	4	2.3	3.0	1.0	3.0	1.9	5	94	21.46	79.77	OY^FSF	2.1	35.7	G	G
AC1-S_3-180-2 x BC1-S_3-115-9	7,349	86	1.3	50	51	243	138	3	2.2	3.0	1.3	3.0	2.0	4	101	18.30	82.00	OYF	2.2	27.0	G	G
AC1-S_3-72-17 x BC1-S_3-115-9	7,345	86	1.0	49	50	241	136	2	1.9	3.0	1.0	3.0	1.8	10	99	19.04	81.76	OY^F	1.7	31.4	G	G
AC1-S_3-21-2 x BC1-S_3-115-9	7,320	85	1.3	52	51	251	142	0	2.1	2.9	1.1	2.9	1.8	6	98	19.10	84.45	OYF	2.1	33.8	G	G
AC1-S_3-21-2 x BC1-S_3-32-19	7,317	85	1.0	52	52	249	144	7	1.9	2.6	1.0	2.6	1.7	4	92	21.14	82.61	OYF	1.9	34.2	G	G
BC1-S_3-186-16 x AC1-S_3-57-4	7,313	85	1.3	53	53	261	147	1	2.3	3.0	1.0	3.0	1.5	9	93	20.47	82.49	OYF	2.0	32.9	G	G
AC1-S_3-175-13 x BC1-S_3-71-1	7,294	85	1.0	52	52	240	140	1	2.2	2.6	1.1	2.6	2.1	3	98	21.38	79.28	OYF	2.7	34.4	G	G
BC1-S_3-115-9 x AC1-S_3-57-4	7,287	85	1.5	51	52	254	142	1	1.4	3.0	1.0	3.0	1.8	3	99	20.87	80.81	OY^FSF	2.4	33.3	G	G
AC1-S_3-72-17 x BC1-S_3-184-16	7,285	85	1.1	51	52	242	132	1	2.1	2.9	1.3	2.9	2.2	6	95	21.40	82.62	OYF	2.6	31.4	G	G
Mean	7,724	90	1.1	51	52	250	143	3	2.4	2.8	1.1	2.9	1.9	3	98	20.52	82.27		2.0	32.4		
Hybrid checks																						
NK 40	8,978	105	1.3	49	50	226	123	1	2.1	2.6	1.0	2.6	1.5	3	99	21.61	83.74	OY^FSF	1.6	29.4	G	G
PAC 999	8,075	94	1.3	51	52	229	130	3	1.7	2.9	1.3	2.9	1.8	2	98	21.52	89.21	OY^FSF	3.1	30.1	G	G
BIG 919	7,169	84	1.1	50	51	210	116	1	1.7	3.0	1.5	3.0	1.9	4	96	20.21	86.95	OY^FSF	2.1	29.1	G	G
DK 888	7,819	91	1.5	53	54	245	150	5	2.5	2.8	1.0	2.9	1.8	4	120	20.63	82.15	OY^FSF	2.6	33.4	G	G
KSX 4601	8,366	98	1.0	50	51	246	149	2	2.1	3.0	1.0	3.0	1.9	1	102	19.45	86.19	OY^F	3.0	27.2	G	G
Suwan 4452 (Check)	8,576	100	1.3	51	52	235	146	6	2.5	2.6	1.0	2.6	1.6	3	97	22.19	86.00	OYF	2.2	29.5	G	G
Mean	8,164	95	1.2	51	52	232	136	3	2.1	2.8	1.1	2.8	1.8	3	102	20.93	85.71		2.4	29.8		
LSD 0.05	1,349.20		0.29	2.02	2.17	10.73	8.49	6.47	0.79	0.37	0.26	0.38	0.48	5.56	6.77	1.95	3.31		1.21	3.97		
LSD 0.01	1,779.50		0.38	2.67	2.86	14.16	11.20	8.54	1.04	0.48	0.34	0.50	0.64	7.34	8.93	2.57	4.37		1.60	5.23		

† G = green.

Appendix Table 9C Mean squares from analyses of variance of eight traits of 100 C1 interpopulation hybrids from data combined over two locations in the 2005 early rainy season.

Source of variation	df	Seed. vigor	Husk cover	Aspect: Plant	Aspect: Ear	Rotten ears	Ears $Plant^{-1}$	Corn borer	Leaf angle
		(1-5)				%		(1-5)	(°)
Locations (L)	1	0.25	0.56	10.40	0.25	2724.41	1.12	490.62	22.09
Replications/L	2	0.08	0.06	0.10	2.00	30.55	41.81	34.22	16.29
Varieties (V)	99	0.07	0.06	0.10	0.20	17.86	77.41	0.69	34.23
Females (A)	9	0.17	0.17	0.35	0.14	43.46	124.18	1.57	216.80 **
Males (B)	9	0.03	0.14	0.27	1.12	51.50	182.92 *	1.59	88.13
A x B	81	0.06	0.03 *	0.06	0.10	11.28	60.49 **	0.49	7.96
L x V	99	0.04	0.03	0.06	0.12	16.34	31.49	0.69	9.64
L x A	9	0.09 *	0.03	0.25 **	0.35 **	31.05 *	43.39	1.57 **	36.20 **
L x B	9	0.02	0.07 **	0.04	0.32 **	37.32 **	44.20	1.59 **	15.77 *
L x (AB)	81	0.04	0.02	0.04	0.07	12.38 **	28.76	0.49	6.00
Pooled error	198	0.04	0.02	0.05	0.08	7.54	34.20	0.54	6.27

*, ** Significant at the 0.05 and 0.01 probability levels, respectively.

Appendix Table 10C Estimates of components of genetic variances of eight traits of 100 C1 interpopulation hybrids from data combined over two locations in the 2005 early rainy season.

Variance	Seed. vigor	Husk cover	Aspect: Plant	Aspect: Ear	Rotten ears	Ears $Plant^{-1}$	Corn borer	Leaf angle
	(1-5)				%		(1-5)	(°)
σ^2_f	0.00	0.00	0.01	0.00	0.80	1.59	0.03	5.22
σ^2_m	0.00	0.00	0.01	0.03	1.01	3.06	0.03	2.00
σ^2_{fm}	0.00	0.00	0.00	0.01	0.93	6.57	-0.01	0.42
σ^2_A	0.00	0.01	0.01	0.03	1.81	4.65	0.05	7.23
σ^2_D	0.00	0.00	0.00	0.01	0.93	6.57	-0.01	0.42
σ^2_D/σ^2_A	1.84	0.69	0.08	0.23	0.52	1.41	-0.24	0.06

Appendix Table 11C Estimates of gca and sca effects of eight traits of 100 C1 interpopulation hybrids from data combined over two locations in the 2005 early rainy season.

Traits	Females†	Males‡										GCA effects
		B1	B2	B3	B4	B5	B6	B7	B8	B9	B10	of females
		SCA effects										
Seedling vigor (1-5)	A1	-0.22 *	-0.06	0.12	-0.19	0.01	0.04	0.15	-0.06	0.28 *	-0.07	0.07 *
	A2	0.32 **	0.10	-0.10	-0.15	-0.07	0.08	0.06	-0.15	-0.19	0.09	0.04
	A3	0.05	-0.16	0.01	-0.04	0.29 *	0.06	-0.20	0.09	-0.20	0.08	0.05
	A4	-0.06	-0.02	0.03	0.10	-0.07	-0.05	0.06	-0.02	0.06	-0.04	-0.09 *
	A5	0.28 *	0.06	-0.01	-0.06	-0.11	0.04	-0.10	0.06	-0.10	-0.07	-0.05
	A6	-0.10	0.06	0.12	-0.06	0.01	-0.09	-0.10	-0.06	0.03	0.18	-0.05
	A7	-0.11	-0.20	-0.15	0.18	0.13	0.03	0.02	0.18	0.02	-0.09	0.09 *
	A8	-0.07	0.09	0.01	0.09	0.04	-0.06	-0.07	-0.04	0.05	-0.05	0.05
	A9	-0.07	0.09	0.01	-0.04	-0.09	0.06	0.05	-0.04	0.05	-0.05	-0.08 *
	A10	-0.01	0.03	-0.05	0.15	-0.15	-0.12	0.12	0.03	-0.01	0.01	-0.01
	GCA effects of males	0.02	-0.01	-0.06	-0.01	0.04	0.01	0.02	-0.01	0.02	0.00	
	SE§ (gca effects)	0.03										
	SE (sca effects)	0.10										
Husk cover (1-5)	A1	0.02	-0.05	-0.11	-0.02	0.11	-0.11	0.05	0.04	0.02	0.04	-0.05 *
	A2	0.03	-0.03	-0.10	-0.01	-0.01	-0.10	0.07	0.05	0.03	0.05	-0.07 **
	A3	-0.05	0.02	-0.05	-0.08	-0.08	0.21 **	-0.01	-0.02	0.08	-0.02	0.01
	A4	-0.01	-0.07	0.24 **	-0.05	-0.05	-0.13	0.03	0.02	-0.01	0.02	-0.03
	A5	-0.08	0.11	0.17 *	0.13	-0.12	0.04	-0.05	-0.06	-0.08	-0.06	0.05 *
	A6	0.00	-0.06	-0.12	-0.03	-0.03	0.00	0.04	0.03	0.13	0.03	-0.04
	A7	0.22 **	0.03	-0.03	-0.07	0.05	-0.16 *	0.00	-0.01	-0.03	-0.01	0.00
	A8	-0.08	-0.02	-0.08	0.13	0.13	0.04	-0.05	0.07	-0.08	-0.06	0.05 *
	A9	-0.06	0.00	0.07	0.03	0.03	0.32 **	-0.15 *	-0.16 *	-0.06	-0.03	0.15 **
	A10	0.00	0.07	0.00	-0.03	-0.03	-0.12	0.04	0.03	0.00	0.03	-0.04
	GCA effects of males	-0.03	0.03	0.10 **	0.01	0.01	0.10 **	-0.07 **	-0.05 *	-0.03	-0.05 *	
	SE (gca effects)	0.02										
	SE (sca effects)	0.07										

Appendix Table 11C (continued)

Traits	Females	Males B1	B2	B3	B4	B5	B6	B7	B8	B9	B10	GCA effects of females
		SCA effects										
Plant aspect (1-5)	A1	-0.10	0.05	0.04	0.22	-0.05	0.01	-0.15	-0.01	-0.08	0.07	-0.01
	A2	-0.13	0.02	-0.24 *	0.32 *	-0.08	-0.01	0.07	-0.04	0.02	0.05	-0.11 **
	A3	-0.23	0.05	0.04	-0.03	0.07	0.01	-0.15	0.11	0.05	0.07	-0.01
	A4	0.11	0.01	0.00	-0.06	0.04	-0.03	-0.06	-0.05	0.01	0.04	0.03
	A5	-0.04	-0.14	-0.03	0.04	0.14	0.07	0.16	0.05	-0.26 *	0.01	-0.07 *
	A6	-0.01	-0.11	0.00	-0.06	0.04	-0.03	0.06	0.07	0.01	0.04	0.03
	A7	0.14	0.04	0.02	-0.16	0.06	0.00	0.21	-0.03	0.04	-0.31 *	-0.12 **
	A8	0.10	0.12	-0.01	-0.08	-0.10	0.09	0.05	-0.19	0.00	0.02	0.16 **
	A9	0.02	0.05	0.04	-0.15	-0.05	-0.11	-0.03	-0.01	0.30 *	-0.05	-0.01
	A10	0.14	-0.09	0.15	-0.04	-0.06	0.00	-0.16	0.10	-0.09	0.06	0.13 **
	GCA effects of males	-0.12 **	0.10 *	-0.14 **	0.05	0.08 *	0.01	0.05	0.04	-0.02	-0.05	
	SE (gca effects)	0.04										
	SE (sca effects)	0.11										
Ear aspect (1-5)	A1	-0.21	0.15	-0.09	-0.01	-0.06	-0.09	0.21	0.23	0.00	-0.13	-0.02
	A2	-0.09	-0.10	-0.21	0.11	0.06	-0.21	0.09	-0.03	0.25	0.13	-0.02
	A3	0.05	0.04	-0.08	0.25	-0.05	0.05	-0.02	-0.26	0.01	0.01	-0.04
	A4	-0.05	0.06	0.08	0.02	-0.15	0.08	-0.13	0.01	0.04	0.04	-0.06
	A5	0.08	-0.31 *	-0.30 *	-0.10	-0.02	0.20	0.00	0.01	0.29 *	0.16	-0.06
	A6	-0.10	-0.11	0.02	0.10	0.30 *	0.03	-0.05	-0.04	-0.26	0.11	-0.01
	A7	-0.05	-0.06	0.33 *	-0.10	0.10	-0.18	0.13	0.01	0.04	-0.21	0.06
	A8	0.14	0.13	0.01	-0.16	0.04	-0.11	0.06	0.08	-0.15	-0.02	0.13 *
	A9	0.13	0.36 *	0.13	0.08	-0.23	0.00	-0.20	-0.19	-0.16	0.09	0.01
	A10	0.11	-0.15	0.11	-0.19	0.01	0.24	-0.09	0.18	-0.05	-0.18	0.02
	GCA effects of males	-0.01	0.13 *	-0.14 **	-0.21 **	-0.04	0.24 **	0.19 **	-0.08	-0.23 **	0.15 **	
	SE (gca effects)	0.04										
	SE (sca effects)	0.14										

Appendix Table 11C (continued)

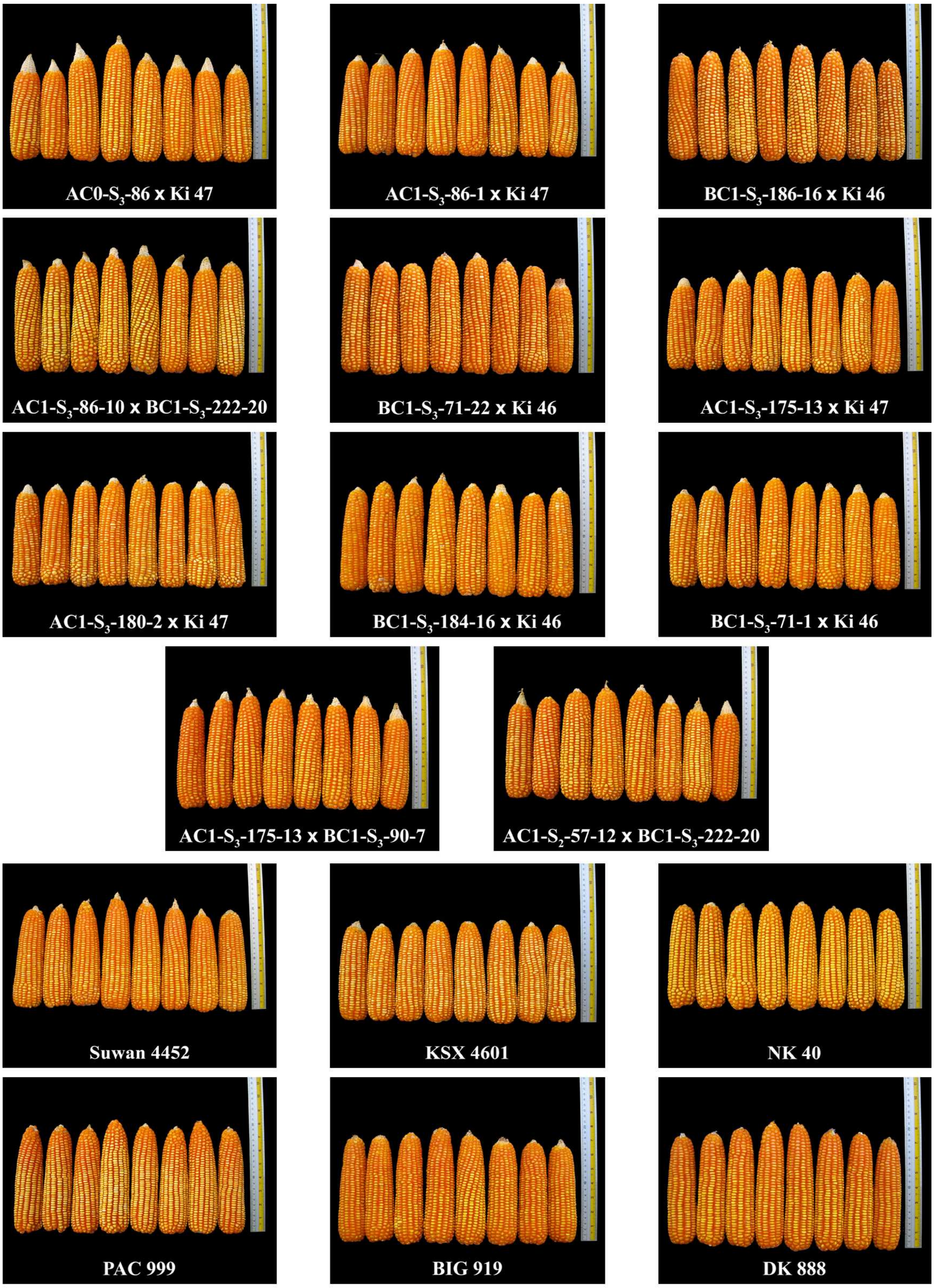
Traits	Females	Males										GCA effects
		B1	**B2**	**B3**	**B4**	**B5**	**B6**	**B7**	**B8**	**B9**	**B10**	**of females**
		SCA effects										
Rotten ears (%)	A1	1.01	0.60	-0.11	1.17	1.29	-0.66	-0.13	-1.87	-1.36	0.04	0.48
	A2	-3.30 *	-0.41	-0.15	4.06 *	-1.86	1.56	0.20	0.03	-0.68	0.55	0.62
	A3	0.29	-0.43	-0.60	-0.29	-0.19	-2.90 *	-0.43	5.08 **	-0.62	0.08	-0.89 *
	A4	1.09	1.74	0.17	-1.23	-0.72	-2.15	0.29	-1.51	2.67	-0.36	-1.62 **
	A5	1.91	-1.35	0.17	-1.26	5.09 **	-0.18	0.64	-2.58	-1.05	-1.39	0.93 *
	A6	0.84	0.79	0.26	-2.77 *	0.19	-1.14	-0.60	2.20	0.11	0.14	-0.15
	A7	-0.60	-0.29	0.97	-1.31	-0.83	0.42	0.78	-0.10	0.90	0.05	-0.54
	A8	-0.95	-0.53	-1.19	0.19	-0.01	0.19	0.41	-0.29	1.83	0.35	0.19
	A9	-0.73	0.06	0.87	1.36	-1.41	0.16	0.54	-3.02 *	0.97	1.21	-0.94 *
	A10	0.43	-0.18	-0.40	0.08	-1.55	4.71 **	-1.70	2.06	-2.77 *	-0.68	1.91 **
	GCA effects of males	-0.65	-1.50 **	-0.84	0.11	0.95 *	1.45 **	-1.53 **	1.68 **	0.22	0.11	
	SE (gca effects)	0.43										
	SE (sca effects)	1.37										
Ears plant^{-1} (%)	A1	-2.73	4.05	3.33	-2.33	0.28	4.94	-7.98 *	5.49	-2.34	-2.70	-1.40
	A2	3.29	-2.86	4.67	-1.08	-1.21	-2.36	0.13	3.20	-2.35	-1.42	0.11
	A3	2.25	-1.03	-2.09	-4.84	0.59	-0.96	3.49	0.51	1.89	0.19	-0.33
	A4	0.04	-1.27	-2.78	-0.84	-1.05	0.25	1.31	6.55 *	-3.22	1.01	0.39
	A5	-5.56	1.54	-0.59	3.02	-0.23	-2.29	1.60	4.48	-1.33	-0.64	0.07
	A6	5.89 *	-0.89	1.36	2.98	-2.66	4.03	-3.24	-11.09 **	1.56	2.08	-0.43
	A7	0.10	-1.19	-1.33	2.29	0.93	-2.13	-1.61	4.15	1.73	-2.93	0.36
	A8	0.16	-2.21	-0.84	-2.27	0.54	-1.07	0.43	4.58	0.23	0.44	1.86 *
	A9	-6.92 *	-1.34	-3.92	4.25	0.82	-2.31	2.54	0.07	3.98	2.83	2.98 **
	A10	3.49	5.22	2.19	-1.18	1.98	1.91	3.34	-17.93 **	-0.16	1.15	-3.61 **
	GCA effects of males	-0.40	2.38 *	2.01 *	-2.57 *	1.69	0.40	1.32	-4.44 **	-0.08	-0.33	
	SE (gca effects)	0.92										
	SE (sca effects)	2.92										

Appendix Table 11C (continued)

Traits	Females	Males										GCA effects of females
		B1	B2	B3	B4	B5	B6	B7	B8	B9	B10	
		SCA effects										
Corn borer (1-5)	A1	-0.17	0.13	-0.07	0.38	-0.17	0.33	0.41	-0.57	-0.19	-0.09	0.04
	A2	-0.17	-0.37	-0.32	-0.12	0.33	0.33	-0.09	-0.32	0.81 *	-0.09	-0.21
	A3	-0.19	-0.14	-0.09	0.86 *	0.56	-0.19	0.38	0.16	-0.72	-0.62	-0.18
	A4	-0.09	0.21	0.26	-0.04	-0.34	-0.59	-0.02	0.51	-0.12	0.23	-0.03
	A5	-0.07	0.23	0.03	-0.27	-0.32	0.68	-0.24	0.53	-0.34	-0.24	-0.31 *
	A6	0.18	-0.52	-0.22	-0.52	0.43	0.18	-0.24	0.03	0.16	0.51	-0.06
	A7	0.18	0.48	0.28	-0.27	-0.07	-0.32	0.26	-0.22	0.16	-0.49	0.19
	A8	0.18	-0.02	0.03	0.23	-0.07	-0.32	-0.49	-0.22	0.41	0.26	0.19
	A9	0.06	0.11	-0.09	0.11	-0.19	-0.19	-0.12	-0.09	0.03	0.38	0.32 *
	A10	0.08	-0.12	0.18	-0.37	-0.17	0.08	0.16	0.18	-0.19	0.16	0.04
	GCA effects of males	-0.23	-0.28 *	0.17	0.22	0.02	0.27 *	-0.06	0.17	-0.21	-0.06	
	SE (gca effects)	0.12										
	SE (sca effects)	0.37										
Leaf angle (°)	A1	0.24	-1.11	1.41	-1.36	0.24	0.00	-2.40	0.96	1.04	1.00	0.80 *
	A2	1.25	2.32	-1.06	-0.57	1.87	1.64	0.71	-2.38	-1.40	-2.36	-0.94 *
	A3	-0.25	2.70 *	-1.46	-0.83	-1.01	-1.02	1.51	1.10	-1.28	0.53	1.29 **
	A4	-1.14	1.50	-2.51 *	0.96	1.53	-1.46	0.71	-0.45	1.95	-1.08	0.96 *
	A5	1.03	0.00	0.37	-0.32	-0.20	0.51	1.01	-0.88	-1.50	-0.01	-2.16 **
	A6	-1.44	-1.17	1.88	2.44	-0.82	0.50	-0.01	1.71	-2.17	-0.90	-0.37
	A7	-0.63	-1.71	-0.39	-0.30	2.19	1.36	-0.67	1.87	-0.63	-1.09	3.77 **
	A8	1.81	-2.54 *	1.38	0.36	-2.15	-0.88	0.57	-0.72	1.23	0.95	-4.92 **
	A9	-0.38	0.37	-0.44	-0.95	-0.66	-0.77	-0.60	0.27	1.52	1.63	0.44
	A10	-0.51	-0.37	0.83	0.59	-0.99	0.12	-0.81	-1.47	1.26	1.35	1.13 *
	GCA effects of males	0.84 *	-1.24 **	-1.95 **	-0.56	0.87 *	0.18	-0.37	-1.81 **	2.77 **	1.28 **	
	SE (gca effects)	0.40										
	SE (sca effects)	1.25										

† A = AC1-S_3, ‡ B = BC1-S_3, § Standard error.

*, ** Exceeds its standard error by two and three times, respectively.



Note: A = Suwan1(S)C11 and B = KS6(S)C3.

Appendix Figure 1C Sample ears of the top-yielding C0 hybrid and the top 10 yielding C1 hybrids compared with six hybrid checks (Suwan 4452, KSX 4601, NK 40, PAC 999, BIG 919 and DK 888).

APPENDIX D

ADDITIONAL DATA FOR INBRED LINE DEVELOPMENT

Appendix Table 1D Mean squares from analyses of variance of 12 traits of C0 lines from data combined over two locations in the 2002 late rainy season.

		Seed.	Husk	Aspect		Rotten	Ears	Branches of tassel[1]		Ear			kernel
Source of variation	**df**	**vigor**	**cover**	**Plant**	**Ear**	**ears**	**Plant^{-1}**	**1°**	**2°**	**length 1[2]**	**length 2[3]**	**width**	**rows**
		(1-5)				%		no.		cm			no.
Locations (L)	1	1.88 **	0.03	6.59 **	5.43 **	986.68 **	37503.17 **	33.52 **	4.23 **	195.46 **	134.63 **	9.83 **	27.11 **
Treatments (T)	55	0.05	0.05 **	0.09 **	0.27	43.78 **	287.18 **	22.84 **	2.72 **	3.66 **	3.52 **	0.11 **	1.94 **
C0 lines	49	0.04	0.05 **	0.10 **	0.20	46.79 *	285.92 **	24.19 **	2.84 **	3.75 **	3.74 **	0.12 **	2.02 **
AC0-S_5	24	0.03	0.08 **	0.07	0.24	62.97 **	146.47	23.36 **	2.40 **	1.75 **	2.13 **	0.06	1.18 *
BC0-S_5	24	0.05	0.01	0.12 **	0.16	6.69	436.04 **	22.79 **	3.11 **	5.67 **	5.08 **	0.15 **	2.56 **
AC0-S_5 vs. BC0-S_5	1	0.28 *	0.32 **	0.14	0.22	620.74 **	29.85	77.49 **	6.88 **	5.47 **	10.44 **	0.67 **	9.22 **
Checks	5	0.09	0.03	0.03	0.84	18.97	91.96	10.35	1.48 *	3.59 *	2.04	0.05	0.53
C0 lines vs. Checks	1	0.00	0.01	0.00	0.41	20.60	1325.21	19.54	3.14	0.02	0.03	0.07	5.06
T x L	55	0.05	0.01	0.04	0.20	22.47	122.47	2.19	0.35	0.65	0.73	0.05	0.60
C0 lines x L	49	0.05	0.01	0.04	0.20	23.79	123.12	1.38	0.37	0.68	0.76	0.05	0.57
Checks x L	5	0.02	0.01	0.03	0.22	12.28	37.30	9.58 **	0.19	0.42	0.54	0.04	0.91
(C0 lines vs. Checks) x L	1	0.02	0.01	0.03	0.10	9.02	516.56	4.57	0.02	0.09	0.27	0.01	0.68
Pooled error	178	0.05	0.03	0.04	0.16	54.80	190.16	2.87	0.25	1.07	1.20	0.05	0.92
CV (%)		17.34	10.94	5.57	16.91	92.12	14.48	14.59	37.73	6.64	7.92	5.76	6.26

*, ** Significant at the 0.05 and 0.01 probability levels, respectively.

[1] Primary and secondary branches of tassel, [2] ear length from ear butt to ear tip and [3] ear length from ear butt to the last point of seed set on the ear tip.

Appendix Table 2D Means of 12 traits and grain type of the selected 25 AC0-S_5 and 25 BC0-S_5 lines compared with the inbred checks from data combined over two locations in the 2002 late rainy season.

Entry	Seed. vigor	Husk cover	Aspect Plant	Aspect Ear	Rotten ears	Ears Plant^{-1}	Grain type	Branches of tassel 1°	Branches of tassel 2°	Ear length 1	Ear length 2	Ear width	kernel rows
	(1-5)				%			no.		cm			no.
The selected 25 AC0-S_5 lines													
AC0-S_4-180	1.3	1.4	3.3	1.9	4	93	YOF	7.6	1.1	13.25	12.61	4.25	12.7
AC0-S_5-72	1.1	1.0	3.7	1.9	4	79	OYF	11.9	2.0	13.84	13.00	3.92	11.9
AC0-S_5-117	1.2	1.4	3.5	2.3	11	78	OYF	9.3	3.2	12.89	11.66	3.82	13.3
AC0-S_5-159	1.0	1.0	3.4	2.0	4	90	OYF	8.1	1.0	12.93	10.87	4.30	13.2
AC0-S_5-145	1.2	1.1	3.5	2.2	5	92	OYF	6.5	0.5	12.10	11.52	3.65	12.4
AC0-S_5-86	1.4	1.0	3.6	2.3	13	74	OYF	11.7	0.1	11.66	10.89	3.82	12.5
AC0-S_5-212	1.2	1.3	3.6	2.6	22	76	OYF	12.4	2.8	11.97	11.44	3.63	12.3
AC0-S_5-204	1.3	1.6	3.6	3.1	8	83	OYF	11.1	4.2	13.69	12.35	3.66	11.5
AC0-S_5-139	1.0	1.6	3.1	2.6	9	71	OYF	9.2	1.5	11.77	10.14	3.98	14.3
AC0-S_5-83	1.3	1.2	3.6	3.1	11	70	OYF	11.1	1.4	11.35	9.60	4.00	13.5
AC0-S_5-96	1.2	1.0	3.8	2.8	13	69	OYF	8.2	1.1	12.08	11.10	3.73	12.5
AC0-S_5-240	1.4	1.0	3.7	2.8	11	71	OYF	10.1	1.1	12.23	11.38	3.88	12.8
AC0-S_5-14	1.3	1.0	3.8	2.6	5	67	OYF	6.7	1.1	12.81	11.02	3.91	11.0
AC0-S_5-4	1.1	1.4	3.6	2.6	9	84	OYF	12.6	2.9	13.59	13.25	3.80	12.1
AC0-S_5-16	1.1	1.3	3.8	2.7	14	81	OYF	14.8	1.6	11.31	9.64	3.66	13.1
AC0-S_5-175	1.3	1.1	3.8	3.0	20	70	OYF	3.4	0.1	11.91	10.59	3.99	13.0
AC0-S_5-228	1.1	1.0	3.6	2.3	2	87	OYF	5.0	0.1	12.53	10.20	3.98	13.3
AC0-S_5-136	1.2	1.0	3.7	2.8	2	69	OYF	7.9	0.7	10.55	9.79	3.91	13.2
AC0-S_5-198	1.3	1.0	3.6	2.6	1	70	OYF	11.3	0.6	13.19	11.60	3.95	11.2
AC0-S_5-57	1.2	1.0	3.6	2.7	2	74	OYF	10.4	2.4	12.21	9.84	4.15	11.9
AC0-S_5-146	1.2	1.0	3.7	2.8	8	66	OYF	5.9	0.4	13.37	11.87	3.96	12.8
AC0-S_5-245	1.2	1.0	3.9	3.0	8	81	OYF	14.7	2.3	12.69	11.63	3.76	12.5
AC0-S_5-55	1.2	1.0	3.3	2.5	3	70	OYF	6.7	1.3	12.87	11.09	3.77	13.3
AC0-S_5-21	1.3	1.0	3.7	2.6	1	64	OYF	15.7	0.5	10.21	9.76	3.66	11.9
AC0-S_5-88	1.1	1.0	3.6	3.1	6	66	OYF	2.9	0.1	11.69	10.89	3.93	13.1
Mean	1.2	1.1	3.6	2.6	8	76		9.4	1.4	12.35	11.11	3.88	12.6

Appendix Table 2D (continued)

Entry	Seed. vigor	Husk cover	Aspect Plant	Aspect Ear	Rotten ears	Ears $Plant^{-1}$	Grain type	Branches of tassel 1°	Branches of tassel 2°	Ear length 1	Ear length 2	Ear width	kernel rows
	(1-5)				%			no.		cm			no.
The selected 25 BC0-S_5 lines													
BC0-S_5-246	1.1	1.0	3.5	2.1	2	79	OYF	10.1	2.8	12.56	11.83	4.26	14.1
BC0-S_5-184	1.3	1.0	3.2	2.3	4	99	YOF	12.4	2.1	14.30	12.82	3.80	12.1
BC0-S_5-296	1.1	1.0	3.5	2.8	3	89	YOF	8.0	2.3	13.51	12.02	3.82	10.9
BC0-S_5-6	1.4	1.0	3.8	2.6	2	107	OYF	11.5	1.3	10.15	8.94	3.97	12.4
BC0-S_5-90	1.1	1.0	3.2	2.1	4	87	OYF	19.9	5.7	12.91	11.46	3.52	12.3
BC0-S_5-140	1.4	1.0	3.4	2.6	1	95	OYF	7.6	0.7	13.90	11.41	3.33	10.9
BC0-S_5-93	1.0	1.0	3.6	2.7	4	77	OYF	9.9	0.9	14.96	14.44	3.77	11.3
BC0-S_5-222	1.6	1.3	3.8	2.8	4	75	OYF	11.9	1.5	12.54	10.86	3.77	13.4
BC0-S_5-45	1.5	1.0	3.6	2.3	8	70	OYF	16.0	3.1	9.99	8.74	3.89	13.5
BC0-S_5-250	1.3	1.0	3.9	2.8	6	60	OYF	10.5	0.3	13.32	12.02	3.94	10.9
BC0-S_5-37	1.4	1.0	3.8	3.0	3	71	OYF	7.3	1.9	12.41	9.75	3.58	12.3
BC0-S_5-280	1.2	1.0	3.7	2.8	1	70	YOF	12.5	1.9	12.25	10.30	3.78	12.4
BC0-S_5-44	1.2	1.0	3.7	2.6	3	81	OYF	9.2	1.8	11.33	10.12	3.41	11.7
BC0-S_4-19	1.4	1.0	3.7	2.9	0	82	YOF	10.6	1.0	13.98	11.99	3.93	11.7
BC0-S_4-200	1.4	1.0	3.8	2.4	1	66	OYF	14.7	1.7	10.06	9.46	3.44	12.8
BC0-S_5-71	1.4	1.1	3.3	2.8	4	93	OYF	8.8	1.4	10.77	10.03	3.44	10.1
BC0-S_5-49	1.5	1.0	3.8	2.8	4	63	OYF	6.2	0.6	10.73	9.50	4.20	13.9
BC0-S_5-122	1.1	1.0	3.7	2.6	3	64	OYF	8.2	1.7	11.75	10.12	3.98	12.4
BC0-S_5-165	1.2	1.0	3.7	2.8	1	65	OYF	15.1	2.3	10.32	8.52	3.73	12.7
BC0-S_5-232	1.3	1.0	4.2	2.9	2	62	OYF	13.0	3.6	8.36	7.40	3.46	12.1
BC0-S_5-47	1.5	1.0	3.9	3.1	1	82	OYF	7.8	0.3	12.26	10.20	3.80	11.9
BC0-S_5-115	1.4	1.0	3.5	2.8	5	70	YOF	8.2	1.1	12.79	11.14	3.85	10.9
BC0-S_5-32	1.4	1.0	3.8	2.8	1	61	OYF	17.0	1.7	9.46	7.97	3.72	13.1
BC0-S_5-186	1.4	1.0	3.7	2.7	2	47	YOF	12.2	4.2	10.25	9.84	3.22	10.3
BC0-S_5-172	1.2	1.0	4.1	3.3	1	53	OYF	10.7	1.3	12.10	10.68	3.34	10.2
Mean	1.3	1.0	3.7	2.7	3	75		11.2	1.9	11.88	10.46	3.72	12.0

Appendix Table 2D (continued)

Entry	Seed. vigor	Husk cover	Aspect Plant	Aspect Ear	Rotten ears	Ears Plant^{-1}	Grain type	Branches of tassel 1°	Branches of tassel 2°	Ear length 1	Ear length 2	Ear width	kernel rows
	(1-5)				%			no.		cm			no.
Inbred checks													
Kei 0101	1.2	1.1	3.4	2.7	10	76	OYF	6.6	0.1	9.77	9.12	3.90	13.3
Kei 0102 (Ki 48)	1.1	1.0	3.7	2.1	4	96	YOF	8.1	1.9	13.84	11.31	4.00	13.0
Ki 44	1.2	1.0	3.8	2.3	3	85	OYF	9.8	1.8	11.62	10.34	3.65	12.3
Ki 45	1.1	1.3	3.6	3.5	2	83	YOF	8.6	0.3	12.32	10.78	3.74	12.6
Ki 46 (Check)	1.6	1.1	3.7	2.6	4	87	OYF	7.5	1.9	12.55	11.76	3.97	13.0
Ki 47 (Check)	1.4	1.1	3.7	1.6	1	91	OYF	13.0	0.5	12.34	11.74	4.03	13.8
Mean	1.3	1.1	3.6	2.4	4	86		8.9	1.1	12.07	10.84	3.88	13.0
LSD 0.05	0.44	0.24	0.41	0.89	9.50	22.18		2.96	1.18	1.61	1.71	0.44	1.55
LSD 0.01	0.58	0.31	0.54	1.18	12.65	29.53		3.95	1.57	2.15	2.28	0.59	2.07

= lines which were components of the 30 high-yielding C0 hybrids, i.e., the top 10 AC0 testcross hybrids, the top 10 BC0 testcross hybrids and the top 10 C0 interpopulation hybrids (Table 4.21).

Appendix Table 3D Mean squares from analyses of variance of 16 traits of C0 and C1 lines from data combined over two locations in the 2005 early rainy season.

Source of variation	df	Seed. vigor	Husk cover	Aspect: Plant	Aspect: Ear	Rotten ears	Ears $Plant^{-1}$	Leaf angle
		(1-5)				%		(°)
Locations (L)	1	0.73 **	1.09 **	2.11 **	0.01	1545.87 **	1981.47 **	126.67 **
Treatments (T)	89	0.12 **	0.06 **	0.16 **	0.41 **	215.05 **	401.24 **	56.70 **
C0 lines	33	0.15 **	0.11 **	0.16 **	0.56 **	201.74 **	470.07 **	54.03 **
$C0\text{-}S_4$	22	0.09	0.15 **	0.11 *	0.49 **	196.76 *	359.58 **	49.31 **
$AC0\text{-}S_4$	12	0.08	0.21 **	0.12 *	0.38 **	263.32 **	344.74 **	54.16 **
$BC0\text{-}S_4$	9	0.06	0.03	0.08	0.41 **	111.65	413.78 **	41.92 **
$AC0\text{-}S_4$ vs. $BC0\text{-}S_4$	1	0.47 **	0.40 **	0.24 *	2.51 **	163.92	49.89	57.59 **
$C0\text{-}S_8$	10	0.19 **	0.05	0.27 **	0.64 **	227.43 *	580.21 **	69.83 **
$AC0\text{-}S_8$	6	0.13	0.06	0.19 **	0.38 **	186.35	480.23 **	24.23 **
$BC0\text{-}S_8$	3	0.21 *	0.00	0.33 **	0.44 *	43.08	165.86	123.24 **
$AC0\text{-}S_8$ vs. $BC0\text{-}S_8$	1	0.51 **	0.13	0.50 **	2.86 **	1026.95 **	2423.20 **	183.20 **
$C0\text{-}S_4$ vs. $C0\text{-}S_8$	1	1.09 **	0.07	0.03	1.24 **	54.44	1799.38 **	0.02
C1 lines	49	0.09 **	0.03	0.13 **	0.34 *	181.73	368.88 **	54.08 **
$AC1\text{-}S_4$	24	0.07 *	0.03	0.15 **	0.41 **	260.33 *	321.14 **	48.07 **
$BC1\text{-}S_4$	24	0.11 **	0.03	0.12 **	0.24	97.56	371.67 **	56.85 **
$AC1\text{-}S_4$ vs. $BC1\text{-}S_4$	1	0.02	0.00	0.00	0.95 *	315.16	1447.71 **	131.83 **
Checks	5	0.12	0.06	0.16 *	0.12	455.13	312.60	104.08 **
C0 and C1 lines vs. Checks	1	0.19	0.11	0.59	0.03	996.67	24.51	73.74
C0 lines vs. C1 lines	1	0.46	0.16	0.94	1.31	304.97	536.01	19.53
T x L	89	0.05	0.02	0.05	0.14 **	117.56 **	109.21	6.11
C0 lines x L	33	0.06	0.03 *	0.05	0.11	82.52	109.24	4.54
C1 lines x L	49	0.04	0.02	0.05	0.17 **	123.29 **	106.36	7.23
Checks x L	5	0.03	0.03	0.02	0.13	158.77 *	125.88	4.29
(C0 and C1 lines vs. Checks) x L	1	0.07	0.03	0.01	0.07	213.39	4.51	11.54
(C0 lines vs. C1 lines) x L	1	0.17	0.00	0.10	0.16	690.93 **	269.81	6.36
Pooled error	142	0.07	0.02	0.04	0.09	68.26	118.18	6.26
CV (%)		14.86	13.75	7.70	16.23	55.35	9.89	8.01

*, ** Significant at the 0.05 and 0.01 probability levels, respectively.

Appendix Table 3D (continued)

Source of variation	df	Tassel length 1(1)	Tassel length 2(2)	Tassel width	Branches of tassel 1°	Branches of tassel 2°	Ear length 1	Ear length 2	Ear width	kernel rows
		cm			no.		cm			no.
Locations (L)	1	0.52	50.67 **	103.17 **	15.84	6.00 **	0.08	0.04	4.07 **	0.69
Treatments (T)	89	23.50 **	19.18 **	78.16 **	38.66 **	3.85 **	3.07 **	3.44 **	0.19 **	2.59 **
C0 lines	33	31.43 **	18.31 **	101.48 **	38.88 **	5.26 **	3.41 **	4.26 **	0.18 **	3.04 **
C0-S_4	22	22.44 **	13.08 **	80.49 **	25.24 **	2.44 **	3.77 **	4.03 **	0.19 **	2.60 **
AC0-S_4	12	13.64 **	8.70 **	95.54 **	29.76 **	2.96 **	2.21 **	3.64 **	0.08 **	1.80 **
BC0-S_4	9	36.66 **	18.49 **	68.77 **	21.52 **	2.01 **	6.09 **	4.85 **	0.27 **	3.01 **
AC0-S_4 vs. BC0-S_4	1	0.15	16.77 **	5.33	4.51	0.09	1.61 *	1.40	0.68 **	8.65 **
C0-S_8	10	42.23 **	19.41 **	142.67 **	72.62 **	11.92 **	2.35 **	4.50 **	0.16 **	4.16 **
AC0-S_8	6	36.64 **	19.26 **	178.19 **	33.67 **	6.38 **	2.02 **	3.79 **	0.15 **	4.12 **
BC0-S_8	3	9.08 **	1.86	72.76 **	131.70 **	23.18 **	2.25 **	6.74 **	0.01	3.24 **
AC0-S_8 vs. BC0-S_8	1	175.27 **	72.90 **	139.31 **	129.05 **	11.41 **	4.66 **	2.03 *	0.66 **	7.07 **
C0-S_4 vs. C0-S_8	1	121.30 **	122.61 **	151.45 **	1.60	0.67	5.98 **	7.01 **	0.31 **	1.38 *
C1 lines	49	17.79 **	18.43 **	63.46 **	33.69	2.75 **	2.47 **	2.40 **	0.19 **	2.30 **
AC1-S_4	24	19.27 **	18.40 **	78.01 **	56.95 **	2.50 **	1.58 **	1.72 **	0.12 **	1.91 **
BC1-S_4	24	16.92 **	17.35 **	51.53 **	11.37	2.65 **	3.41 **	3.11 **	0.14 **	2.48 **
AC1-S_4 vs. BC1-S_4	1	2.97	45.14 **	0.54	10.92	11.42 **	1.28	1.67 *	3.21 **	7.37 **
Checks	5	15.56 **	28.05 **	66.00 **	42.68 **	1.29 **	6.67 *	6.36 **	0.09	1.21 *
C0 and C1 lines vs. Checks	1	54.09	0.02	80.54	196.56 *	22.10 *	0.60	10.66	0.25 *	11.17
C0 lines vs. C1 lines	1	51.15 *	58.94 *	87.08	97.40	5.97 *	6.05	5.21	0.36	0.33
T x L	89	1.99	1.08	9.30	13.07	0.31	0.41	0.40	0.01	0.20
C0 lines x L	33	1.04	0.87	9.54	1.18	0.53	0.36	0.43	0.01	0.22
C1 lines x L	49	2.72	1.26	9.42	22.68	0.19	0.41	0.34	0.01	0.18
Checks x L	5	1.05	1.04	5.70	0.19	0.05	0.66	0.52	0.02	0.21
(C0 and C1 lines vs. Checks) x L	1	3.55	0.21	8.44	0.84	0.04	0.21	0.21	0.00	0.28
(C0 lines vs. C1 lines) x L	1	0.19	0.02	14.54	10.96	0.01	1.55	1.18	0.02	0.50
Pooled error	142	2.55	1.73	8.74	24.94	0.43	0.46	0.47	0.02	0.31
CV (%)		3.91	3.36	18.63	32.01	25.61	4.57	4.81	2.79	3.55

*, ** Significant at the 0.05 and 0.01 probability levels, respectively.

(1) Tassel length from the point where the tassel starts to the tip of main stem of tassel and (2) tassel length from the point where the panicle branch of tassel starts to the tip of main stem of tassel.

Appendix Table 4D Means of 16 traits, grain type and colors of some parts of the selected 25 AC1-S_4 and 25 BC1-S_4 lines and the selected C0 lines compared with the inbred checks from data combined over two locations in the 2005 early rainy season.

	Seed.	Husk	Aspect		Rotten	Ears	Grain	Leaf	Tassel			Branches of tassel		Ear			kernel	Color†			
Entry	vigor	cover	Plant	Ear	ears	Plant^{-1}	type	angle	length 1	length 2	width	1°	2°	length 1	length 2	width	rows	Stalk	Midrib	Anther	Glume
	(1-5)				%			(°)	cm			no.		cm			no.				
The selected 25 AC1-S_4 lines																					
AC1-S_4-72-17	1.3	1.0	2.5	1.8	18	112	OYF	28.9	39.34	34.33	15.06	13.6	3.3	15.85	14.87	4.07	13.1	G	G	Y	GP
AC1-S_4-175-13	1.6	1.0	2.4	2.6	34	111	OYF	42.7	38.50	33.02	22.40	6.5	0.1	15.28	14.83	4.09	13.4	G	G	YP, Y	GP
AC1-S_4-146-17	1.2	1.0	2.9	1.8	27	98	OYF	29.1	39.66	36.02	23.88	13.1	3.7	14.74	13.62	4.55	13.0	G	G	P, YP	PG, GP
AC1-S_4-83-18	1.2	1.1	2.8	2.0	16	104	OYF	32.8	34.97	32.58	13.98	10.4	2.9	14.87	14.68	4.19	12.9	G	G	YP	GP
AC1-S_3-204-14	1.4	1.4	2.6	1.4	6	119	OYF	33.7	32.08	27.34	14.66	13.8	2.5	14.08	12.59	4.36	13.2	G	G	Y	GP
AC1-S_4-86-1	1.8	1.3	2.3	1.6	12	103	OYF	31.7	32.29	28.41	6.48	11.7	2.2	15.69	14.21	4.44	12.8	G	G	P, YP	GP
AC1-S_4-21-2	1.6	1.0	3.0	2.1	34	101	OF	27.5	38.73	33.94	26.70	14.9	2.4	13.67	13.33	4.05	13.9	G	G	Y	GP
AC1-S_4-88-15	1.3	1.0	3.1	2.6	30	92	OYF	36.0	30.12	28.76	8.19	6.8	1.4	14.49	13.66	4.39	14.3	G	G	Y	GP, G
AC1-S_4-72-5	1.3	1.3	2.6	2.0	16	108	OYF	32.9	37.63	31.13	20.13	15.6	2.5	13.74	12.91	3.97	11.4	G	G	Y	GP, G
AC1-S_3-245-17	1.3	1.1	2.9	1.9	16	103	OYF	24.3	35.81	29.66	15.03	13.0	2.3	14.37	12.61	4.01	11.1	G	G	YP, Y	GP
AC1-S_4-88-13	1.7	1.1	2.8	2.5	44	125	OYF	35.8	35.80	33.12	15.95	6.8	0.1	14.66	12.24	4.48	13.6	G	G	P, YR	GP
AC1-S_4-86-13	1.4	1.0	2.8	1.1	20	94	OF	30.8	35.37	33.18	20.61	14.2	1.3	12.44	11.97	4.44	13.8	G	G	P, YR	GP
AC1-S_4-180-2	1.2	1.1	3.2	2.1	6	106	OYF	20.2	37.07	31.58	17.08	7.8	0.8	14.11	12.88	4.20	11.6	G	G	Y	G
AC1-S_4-204-6	1.3	1.4	2.9	2.0	10	124	OYF	31.4	31.67	25.13	10.65	12.3	5.1	12.14	11.65	4.19	14.5	G	G	Y	GP
AC1-S_4-57-4	1.4	1.0	2.8	1.9	5	96	OYF	35.2	32.76	30.96	22.45	12.2	1.7	13.97	13.61	3.88	11.5	G	G	Y	GP
AC1-S_3-245-20	1.4	1.0	3.0	2.4	14	92	OYF	27.4	36.08	30.20	24.78	10.3	2.3	13.77	12.39	4.52	12.5	G	G	Y	G
AC1-S_3-228-3	1.2	1.0	3.2	2.1	8	108	OYF	32.7	39.61	35.95	17.89	9.9	0.8	14.60	13.19	3.55	12.1	G	G	Y	G
AC1-S_4-55-9	1.6	1.0	2.6	2.5	10	85	OYF	43.2	38.32	34.56	31.91	33.9	1.9	14.37	13.12	4.32	13.3	G	G	P	GP
AC1-S_4-159-19	1.5	1.1	2.5	2.3	10	105	OYF	34.3	36.79	31.47	13.37	9.7	2.3	13.47	11.61	4.32	12.7	G	G	Y	GP, G
AC1-S_3-57-12	1.3	1.0	3.2	2.4	16	99	OYF	34.9	36.19	29.92	10.33	10.7	2.6	13.73	13.13	4.15	13.2	G	G	Y	GP, G
AC1-S_4-86-10	1.2	1.3	2.9	2.9	40	79	OYF	31.6	31.67	30.09	9.58	8.7	1.4	14.54	13.32	3.87	13.6	G	G	P, Y	GP
AC1-S_3-228-8	1.4	1.0	3.1	2.3	28	77	OF	30.8	41.47	38.34	21.37	10.9	2.0	13.06	11.84	4.25	14.1	G	G	YP	GP
AC1-S_4-14-11	1.6	1.0	3.2	2.9	11	90	OF	30.2	34.33	31.21	18.83	16.5	2.1	13.79	12.82	3.97	11.4	G	G	Y	G
AC1-S_4-228-13	1.2	1.1	3.0	2.6	24	93	OYF	28.5	36.22	34.60	11.11	13.3	1.0	13.74	12.33	4.19	12.0	G	G	P	GP
AC1-S_4-21-9	1.1	1.0	2.7	2.8	36	83	OYF	30.6	40.95	35.23	14.24	17.0	3.2	13.09	12.55	3.86	12.2	G	G	P, Y	GP
Mean	1.4	1.1	2.8	2.2	20	100		31.9	36.14	32.03	17.07	12.5	2.1	14.09	13.04	4.17	12.8				

Appendix Table 4D (continued)

Entry	Seed. vigor	Husk cover	Aspect Plant	Aspect Ear	Rotten ears	Ears $Plant^{-1}$	Grain type	Leaf angle	Tassel length 1	Tassel length 2	Tassel width	Branches of tassel 1°	Branches of tassel 2°	Ear length 1	Ear length 2	Ear width	kernel rows	Color Stalk	Color Midrib	Color Anther	Color Glume
	(1-5)				%			(°)	cm			no.		cm			no.				
The selected 25 BC1-S_4 lines																					
BC1-S_4-186-16	1.5	1.1	2.9	1.6	11	100	OYF	24.0	38.45	32.43	15.52	10.4	2.9	16.00	15.60	3.87	13.4	G	G	Y	GP
BC1-S_4-184-16	1.4	1.1	2.7	2.3	20	141	OYF	27.5	41.49	32.55	9.48	11.6	1.7	14.34	12.57	3.82	11.5	G	G	P, YP	G
BC1-S_4-172-19	1.5	1.0	2.8	2.1	23	105	OY^F	24.7	39.26	33.94	22.46	13.9	2.9	15.64	14.84	3.82	11.6	G	G	Y	GP
BC1-S_4-90-12	1.3	1.0	2.7	2.3	18	103	OYF	21.5	35.32	27.86	15.91	12.9	2.7	13.91	13.22	3.80	11.1	G	G	Y	GP
BC1-S_4-32-20	1.2	1.3	3.0	2.0	15	95	OYF	36.2	35.99	30.38	21.62	15.0	2.8	13.07	12.41	4.17	12.9	G	G	Y	PG
BC1-S_4-222-20	1.5	1.0	2.3	2.3	17	120	OYF	31.8	40.28	36.63	20.13	9.2	2.7	17.32	16.31	3.81	11.7	G	G	Y	GP
BC1-S_4-186-3	1.3	1.0	3.1	2.1	11	115	OY^F	27.7	33.19	28.57	15.70	10.8	5.2	13.26	12.99	3.63	11.8	G	G	Y	GP
BC1-S_4-90-7	1.0	1.0	3.0	1.9	6	111	OYF	29.8	36.92	31.71	16.39	11.4	2.5	14.99	14.38	3.90	12.8	G	G	Y	GP
BC1-S_3-280-3	1.0	1.0	2.7	2.5	22	118	OY^F	31.7	35.60	29.92	19.28	14.3	3.8	15.05	13.14	3.88	13.0	G	G	YP	GP
BC1-S_4-71-1	1.4	1.1	2.6	2.4	15	118	OYF	23.0	37.35	31.37	17.37	11.0	3.1	13.98	13.02	3.72	12.9	G	G	YP	GP, G
BC1-S_4-184-9	1.7	1.4	2.7	2.4	30	131	OF	26.6	30.93	27.27	9.13	14.9	3.2	13.79	13.03	3.82	14.1	G	G	Y	GP
BC1-S_4-90-2	1.6	1.0	2.8	2.3	16	119	OYF	25.1	39.50	33.34	21.17	11.8	4.8	14.52	13.29	3.75	10.5	G	G	Y	GP
BC1-S_4-184-4	1.7	1.1	2.6	3.3	34	106	OYF	29.4	33.22	25.20	13.43	13.9	2.4	10.99	10.98	4.09	13.8	G	G	Y	GP
BC1-S_4-47-9	1.3	1.1	3.2	2.4	16	96	OY^F	31.9	39.53	33.95	15.71	14.6	2.1	12.81	11.93	4.17	13.9	G	G	Y	GP, G
BC1-S_4-186-20	1.4	1.4	2.6	2.3	28	104	OYF	37.6	35.27	29.89	18.03	12.3	5.1	14.14	13.69	3.72	11.7	G	G	Y	G
BC1-S_4-71-22	1.9	1.1	2.8	2.4	17	94	OYF	38.3	33.41	26.40	12.22	10.8	1.9	14.97	14.53	3.85	13.0	G	G	Y	GP, G
BC1-S_4-115-7	1.3	1.0	2.8	2.3	11	102	YOF	37.1	36.42	32.76	28.31	10.8	2.8	14.26	12.83	4.04	12.3	G	G	Y	PG, GP
BC1-S_4-115-6	1.3	1.0	2.8	2.3	8	87	OYF	27.8	40.89	29.03	13.13	8.1	0.6	16.20	14.82	3.89	13.0	G	G	Y	GP, G
BC1-S_4-246-11	1.3	1.0	2.7	2.5	10	111	OY^F	31.6	35.58	31.48	18.09	17.0	2.9	14.93	13.16	4.12	14.2	G	G	Y	GP
BC1-S_4-115-9	1.5	1.0	3.2	2.6	14	112	OYF	29.7	33.83	24.47	10.17	7.6	1.0	15.06	11.82	3.63	12.1	G	G	Y	GP, G
BC1-S_4-32-19	1.3	1.0	2.7	2.3	9	106	OYF	34.2	32.40	29.36	24.13	9.5	1.5	14.37	12.61	3.76	11.3	G	G	YP	GP
BC1-S_4-296-2	2.0	1.0	2.8	2.8	14	93	OYF	33.6	34.27	32.73	16.59	14.2	2.7	12.35	11.70	3.90	12.3	G	G	Y	GP
BC1-S_4-296-19	1.5	1.3	3.1	2.9	17	100	OYF	32.7	36.93	30.56	10.33	11.9	3.6	13.57	12.93	3.83	11.3	G	G	Y, G	PG, GP
BC1-S_4-115-19	1.2	1.0	3.3	2.5	8	85	OYF	29.5	35.46	31.60	25.76	9.0	1.2	13.82	12.60	3.54	10.7	G	G	Y	GP
BC1-S_4-37-6	1.2	1.0	3.4	3.0	12	125	OYF	16.5	40.58	33.77	20.29	10.2	2.7	14.58	14.03	2.81	10.6	G	G	Y	G
Mean	1.4	1.1	2.8	2.4	16	108		29.6	36.48	30.69	17.21	11.9	2.7	14.32	13.30	3.81	12.3				

Appendix Table 4D (continued)

Entry	Seed. vigor	Husk cover	Aspect Plant	Aspect Ear	Rotten ears	Ears Plant^{-1}	Grain type	Leaf angle	Tassel length 1	Tassel length 2	Tassel width	Branches of tassel 1°	Branches of tassel 2°	Ear length 1	Ear length 2	Ear width	kernel rows	Color Stalk	Color Midrib	Color Anther	Color Glume
	(1-5)				%			(°)	cm			no.		cm			no.				
The 13 AC0-S_4 lines which were components of the 30 high-yielding C0 hybrids																					
AC0-S_4-96	0.9	1.4	2.8	1.5	16	100	OYF	31.1	42.39	35.85	28.48	15.0	2.8	16.50	16.14	4.00	13.8	G	G	P, Y	PG, GP
AC0-S_4-86	1.5	1.3	2.7	1.8	19	120	OYF	40.8	35.62	31.82	21.01	17.6	1.9	14.52	13.66	4.11	13.5	G	G	P, Y	GP
AC0-S_4-180	1.1	1.1	2.5	1.6	10	124	OYF	29.9	34.87	30.08	27.28	7.7	1.6	13.30	12.99	4.21	12.5	G	G	Y	G
AC0-S_4-204	1.2	2.0	2.7	1.8	16	125	OF	34.1	36.87	30.96	16.04	12.7	3.6	14.26	13.17	4.15	13.6	G	G	Y	GP
AC0-S_4-4	1.6	1.9	2.9	2.3	56	114	OYF	25.9	36.85	30.80	21.01	14.3	3.8	14.84	14.54	3.97	12.4	G	G	P	GP
AC0-S_4-146	1.3	1.3	2.8	2.0	20	97	OYF	31.6	37.03	33.04	17.13	5.9	0.5	14.56	14.10	4.06	13.1	G	G	Y	GP
AC0-S_4-159	1.3	1.0	2.7	2.1	24	100	OYF	40.9	34.64	28.97	9.90	10.1	2.0	14.43	13.20	4.41	12.9	G	G	Y	GP
AC0-S_4-57	1.2	1.1	3.0	2.6	23	104	OYF	34.2	37.55	33.69	16.70	10.3	2.8	14.91	13.06	4.26	12.3	G	G	P, Y	GP
AC0-S_4-72	1.3	1.0	3.0	2.3	24	106	OYF	32.4	38.11	32.67	9.40	12.5	2.8	14.55	13.19	3.92	11.1	G	G	YP	GP
AC0-S_4-136	1.3	1.1	3.1	2.6	20	109	OYF	38.5	33.21	29.88	13.63	10.3	1.1	12.30	11.45	3.93	13.6	G	G	Y	GP
AC0-S_4-14	1.4	1.1	3.3	2.1	16	90	OYF	29.7	35.99	33.48	21.82	9.4	1.9	13.90	12.58	3.75	11.6	G	G	P, Y	GP
AC0-S_4-88	1.7	1.0	3.1	3.0	34	97	OYF	26.4	32.51	28.49	4.73	4.6	0.1	13.07	12.64	4.21	14.2	G	G	Y	GP
AC0-S_4-228	1.4	1.0	3.4	2.4	21	80	OF	25.7	33.11	31.19	13.93	6.0	0.2	13.28	10.65	3.70	13.9	G	G	P, Y	GP
Mean	1.3	1.3	2.9	2.2	23	105		32.4	36.06	31.61	17.00	10.5	1.9	14.19	13.18	4.05	12.9				
The 10 BC0-S_4 lines which were components of the 30 high-yielding C0 hybrids																					
BC0-S_4-90	1.6	1.0	3.0	1.9	22	93	OY^F	24.3	33.61	28.58	9.07	17.7	2.6	14.89	14.10	4.07	12.6	G	G	YP	GP
BC0-S_4-250	1.8	1.0	3.4	2.0	19	91	OY^F	31.3	33.59	30.12	20.58	12.8	1.1	15.80	14.79	4.18	13.1	G	G	Y	PG
BC0-S_4-140	1.6	1.0	2.9	2.4	14	132	OYF	29.2	38.48	32.02	15.51	10.4	3.0	16.27	14.87	3.37	12.2	G	G	Y	G
BC0-S_4-47	1.4	1.1	3.2	2.8	14	118	OY^F	27.6	37.81	30.70	22.32	7.4	1.2	13.52	12.28	3.90	12.3	P	P	Y	PG, GP
BC0-S_4-184	1.8	1.0	3.0	2.6	28	114	OYF	23.4	36.36	28.39	8.55	11.4	1.4	12.23	12.04	3.39	12.2	G	G	Y	GP, G
BC0-S_4-186	1.3	1.4	3.0	2.5	23	90	OYF	36.7	37.66	33.67	22.10	14.9	3.7	13.28	13.00	3.80	12.1	G	G	YP, Y	GP
BC0-S_4-296	1.4	1.0	3.0	3.3	26	105	OYF	33.4	36.23	32.72	24.44	10.8	3.0	14.85	13.57	3.66	10.8	G	G	Y	PG
BC0-S_4-49	1.4	1.0	3.4	3.0	27	95	OYF	29.2	45.14	34.42	11.77	8.2	0.8	11.91	10.91	4.53	14.5	G	G	P	PG, GP
BC0-S_4-71	1.7	1.1	2.9	2.8	13	89	OYF	29.5	28.58	24.13	11.73	9.7	1.6	10.92	10.20	3.52	10.5	G	G	Y	GP
BC0-S_4-115	1.4	1.0	2.8	3.1	5	103	YOF	36.9	34.29	29.17	17.09	7.8	1.9	14.41	12.57	3.64	10.6	G	G	P, Y	GP
Mean	1.5	1.1	3.1	2.6	19	103		30.1	36.17	30.39	16.32	11.1	2.0	13.81	12.83	3.81	12.1				

Appendix Table 4D (continued)

Entry	Seed. vigor	Husk cover	Aspect Plant	Aspect Ear	Rotten ears	Ears Plant^{-1}	Grain type	Leaf angle	Tassel length 1	Tassel length 2	Tassel width	Branches of tassel 1°	Branches of tassel 2°	Ear length 1	Ear length 2	Ear width	kernel rows	Color Stalk	Color Midrib	Color Anther	Color Glume
	(1-5)				%			(°)	cm			no.		cm			no.				
The 7 AC0-S_8 lines which were components of the top 10 C0 hybrids																					
AC0-S_8-180	1.4	1.3	2.4	1.9	7	132	OYF	32.8	34.92	30.15	29.98	8.6	2.0	13.14	13.05	4.02	12.9	G	G	Y	G
AC0-S_8-96	2.1	1.0	3.3	2.1	6	115	OYF	35.1	34.78	28.76	16.09	11.5	1.1	13.82	13.53	4.07	13.5	G	G	Y	GP
AC0-S_8-72	1.4	1.4	3.1	2.4	25	120	OYF	36.0	36.24	30.84	10.93	13.2	2.4	13.84	12.84	3.87	11.4	G	G	P, YR	GP
AC0-S_8-204	1.4	1.4	2.8	2.3	14	119	ORF	28.2	31.12	26.47	11.57	11.6	5.1	13.98	13.04	3.46	10.2	G	G	Y	G
AC0-S_7-228	1.6	1.0	2.9	2.5	8	152	OYF	30.1	25.75	24.20	6.44	7.0	0.1	11.82	9.71	3.71	14.3	G	G	YP	GP, G
AC0-S_8-159	1.4	1.0	2.9	2.3	9	122	OYF	38.1	26.76	24.18	4.97	7.4	0.8	13.19	11.41	4.12	13.0	G	G	Y	GP
AC0-S_6-88	1.6	1.1	3.0	3.3	30	103	OYF	35.2	28.29	23.24	1.31	0.9	0.0	11.49	11.21	4.28	13.6	G	G	Y	GP, G
Mean	1.6	1.2	2.9	2.4	14	123		33.6	31.12	26.83	11.61	8.6	1.6	13.04	12.11	3.93	12.7				
The 4 BC0-S_8 lines which were components of the top 10 C0 hybrids																					
BC0-S_8-90	1.6	1.0	2.6	2.5	33	114	OYF	22.0	35.78	30.12	8.18	24.6	8.2	14.77	13.86	3.64	13.1	G	G	Y	G
BC0-S_7-296	1.7	1.0	3.3	3.3	27	100	OY^F	27.7	38.22	31.67	21.16	7.6	2.1	13.49	12.14	3.62	10.5	G	G	Y	PG, GP
BC0-S_8-250	2.2	1.0	3.6	3.1	31	92	OYF	38.7	34.67	29.54	17.30	15.0	1.5	14.98	14.54	3.55	12.0	G	G	Y	PG
BC0-S_7-47	2.1	1.0	3.4	3.6	23	99	OYF	22.2	39.28	31.14	20.74	7.4	0.7	12.75	10.45	3.48	10.5	P	P	Y	GP
Mean	1.9	1.0	3.2	3.1	28	101		27.6	36.99	30.62	16.84	13.6	3.1	14.00	12.75	3.57	11.5				
Inbred checks																					
Kei 0102 (Ki 48)	1.4	1.5	2.2	2.1	33	97	OYF	19.5	41.98	36.10	16.40	8.5	0.6	17.04	16.60	4.36	14.0	G	G	Y, YP	GP, G
Kei 0303	1.6	1.0	3.0	2.6	42	100	OYF	34.4	41.08	31.25	13.64	5.2	0.0	15.35	15.33	3.95	14.5	G	G	Y	G
Kei 0301	2.0	1.1	2.7	2.0	6	125	OYF	19.0	36.84	29.80	7.48	1.5	0.0	12.05	12.00	3.81	12.3	G	G	Y	G
Ki 45	1.3	1.3	2.5	2.1	24	122	OY^F	31.0	37.14	33.59	8.46	5.8	1.7	13.87	13.08	4.25	13.2	G	G	P, YP	GP
Ki 46 (Check)	1.6	1.3	2.9	2.4	19	99	OYF	33.2	35.97	29.59	23.28	8.1	1.9	14.70	14.49	4.24	14.0	G	G	Y	G
Ki 47 (Check)	1.5	1.1	2.8	2.5	46	101	OYF	33.6	35.29	25.17	13.93	15.3	0.9	12.66	12.49	4.02	13.3	G	G	PY, Y	PG
Mean	1.6	1.2	2.7	2.3	28	107		28.5	38.05	30.92	13.86	7.4	0.8	14.28	14.00	4.11	13.5				
LSD 0.05	0.43	0.31	0.44	0.76	21.54	20.77		4.91	2.80	2.06	6.06	7.18	1.10	1.28	1.25	0.22	0.89				
LSD 0.01	0.57	0.40	0.59	1.00	28.54	27.51		6.51	3.71	2.73	8.03	9.51	1.45	1.69	1.66	0.29	1.18				

† G = green, P = purple, Y = yellow, GP = green-purple, PG = purple-green, YP = yellow-purple, PY = purple-yellow and YR = yellow-red.

= lines which were components of the 30 high-yielding C1 hybrids, i.e., the top 10 AC1 testcross hybrids, the top 10 BC1 testcross hybrids and the top 10 C1 interpopulation hybrids (Table 4.27).

Note: A = Suwan1(S)C11 and B = KS6(S)C3.
The photograph of AC1-S_4-88-13 line was not available.

Appendix Figure 1D Sample ears of the three C0 and 10 C1 lines which were components of the high-yielding hybrids and had high yield compared with six inbred checks (Kei 0102 or Ki 48, Kei 0303, Kei 0301, Ki 45, Ki 46 and Ki 47).

APPENDIX E

COLLECTION OF DATA FOR HYBRID AND INBRED LINE DESCRIPTION

E.1 Collection of data for hybrid description

In the hybrid yield trial (2005E), data collected for hybrid description were leaf angle and colors of stalk and midrib. A brief description of each trait is provided as follows:

1. Leaf angle (degrees; °): An angle of the first leaf over the uppermost ear in degrees (°) from 10 random plants in each plot were recorded. The average leaf angle can be classified on the 1 to 5 scale described below (Department of Agriculture, Unpublished manuscript, n.d.).

1 = Very narrow (< 5°)

2 = Narrow (± 25°)

3 = Moderate (± 50°)

4 = Wide (± 75°)

5 = Very wide (> 90°)

2. Colors of stalk and midrib: Colors of stalk and midrib of plants in each plot, while the stalks and leaves were still fresh, were record. The colors of stalk and midrib can be green (G) or purple (P).

E.2 Collection of data for inbred line description

In the inbred yield trial (2002L), data collected for inbred line description were number of primary and secondary panicle branches of tassel, ear length, ear width and number of kernel rows. In the inbred yield trial (2005E), leaf angle, tassel length, tassel width, and colors of stalk, midrib, anther and glume were also collected. A brief description of each trait is provided as follows:

1. Number of primary and secondary panicle branches of tassel: For each plot, the tassels of 10 random plants at below the point where the tassel starts were cut. The numbers of (i) primary branches and (ii) secondary branches of each tassel were recorded.

2. Tassel length (cm): For the same 10 tassels whose panicle branches were recorded, the tassel length in centimeters from (i) the point where the tassel starts to the tip of main stem of tassel and (ii) the point where the panicle branch of tassel starts to the tip of main stem of tassel were measured.

3. Tassel width (cm): For the same 10 tassels whose lengths were recorded, the tassel widths in centimeters in the widest part of tassel were measured.

4. Ear length (cm): For 10 ears selected at random in each plot, the ear length in centimeters from (i) ear butt to ear tip and (ii) ear butt to the last point of seed set on the ear tip were measured.

5. Ear width (cm): For the same 10 ears whose lengths were measured, the ear widths in centimeters from the middle of ear were determined.

6. Number of kernel rows: For the same 10 ears whose widths were measured, the numbers of kernel rows were counted.

7. Colors of stalk, midrib, anther and glume: Colors of stalk, midrib, anther and glume of plants in each plot, while the stalks, leaves and tassels were still fresh, were recorded. The colors of stalk and midrib can be green (G) or purple (P). The colors of anther can be green, yellow, pink, red or purple. The colors of glume can be pale green, green, pink, red or purple (Department of Agriculture, Unpublished manuscript, n.d.).

BIOGRAPHY

Miss Sujin Jenweerawat was born in Ratchaburi province on November 7, 1976. She received a Bachelor degree of Science (Crop Production Technology) in 1998 from School of Crop Production Technology, Suranaree University of Technology. After graduation, she worked as research officer for three years at T.C.C. Agriculture Co., Ltd. and Bionic Humus Co., Ltd., respectively. She received the 2001 Royal Golden Jubilee Ph.D. research assistant fellowship from the Thailand Research Fund (TRF) to pursue a Ph.D. degree in the School of Crop Production Technology, Suranaree University of Technology under the supervision of Prof. Dr. Paisan Laosuwan. Her outstanding achievements and publications are as follows:

(a) A certificate of oral presentation, Topic: "Progress from Modified Reciprocal Recurrent Selection in Suwan 1 and KS 6 Maize Populations." In The 2004 Technical Meeting of the Senior Research Scholars' Projects in Field Crops and the RGJ Seminar Series XXVIII: Field Crops, at the Imperial Phukaew Hill Resort, Khaokho, Petchaboon, May 6-7, 2004.

(b) An honorary award of outstanding academic achievement for graduate student. In The 15th Anniversary of Suranaree University of Technology, July 27, 2005.

1. Jenweerawat, S., Aekatasanawan, C., Laosuwan, P. and Hallauer, A.R. (in press). Interpopulation Hybrid Development in Maize Using Modified Reciprocal Recurrent Selection. **Thai J. Agric. Sci.** 42(3).
2. Jenweerawat, S., Aekatasanawan, C., Laosuwan, P. and Hallauer, A.R. (in press). Potential Lines and Hybrids Developed from Modified Reciprocal Recurrent Selection in Maize. **Kasetsart J. (Nat. Sci.).**