

THESIS

**DEVELOPMENT OF SWEET CORN (*Zea mays* L.)
INBRED LINES BY FAMILY SELECTION
UNDER DIFFERENT COMPETITION
ENVIRONMENTS**

NGUYEN TIEN TRUONG

**GRADUATE SCHOOL, KASETSART UNIVERSITY
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NAME: Mr. Nguyen Tien Truong

THIS THESIS HAS BEEN ACCEPTED BY

Krisda Samphantharak

THESIS ADVISOR

(Professor Krisda Samphantharak, Ph.D.)

Wasana Wongyai

COMMITTEE MEMBER

(Associate Professor Wasana Wongyai, D.Agr.)

P. Sripichitt

COMMITTEE MEMBER

(Associate Professor Prapa Sripichitt, D.Agr.)

Somnuk Wongtong

PROGRAM CHAIRMAN

(Associate Professor Somnuk Wongtong, Ph.D.)

APPROVED BY THE GRADUATE SCHOOL ON 19 december, 2005

Vinai Artkongharn

DEAN

(Associate Professor Vinai Artkongharn, M.A.)

THESIS

DEVELOPMENT OF SWEET CORN (*Zea mays* L.) INBRED LINES BY FAMILY SELECTION UNDER DIFFERENT COMPETITION ENVIRONMENTS

NGUYEN TIEN TRUONG

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Family selection was applied in segregated populations of three single crosses in three different environments. Firstly, isolation environment in non-replicated honeycomb design (HC). Secondly, high plant density environment (HD). Thirdly, alternate environments of the first two methods (HC-HD). Each of the 9 sets composed of 3 lines, total of 27 lines. They were selfed and selected in the 3 assigned environments to obtain 3 S₃HC, 3 S₃HD and 3 S₃ HC-HD for each family, total of 9 sets of 3 S₃ lines.

Diallel crosses were applied within each set and the best recovered hybrid of each set was testcrossed to lines within set to obtain 27 within set testcross hybrids. Simultaneously, the 9 best recovered hybrids were diallel crossed to form 36 sister line crosses (A/A'//B/B').

The results showed that selection for inbred line performance per se was effective under isolation environment in non-replicated honeycomb design, alternate environments and high plant density environment, respectively. High yield lines had a tendency to render high yield hybrids. However, the average yield of recovered hybrids (A/A') of each set were statistically not different. The sister line crosses (A/A'//B/B') either H x H or H x L crosses were uniformed and had high yielding ability. Therefore, selection for inbred line performance per se combined with testing for combining ability is necessary to identify useful single cross hybrid combination. Besides, sister line cross has potential to be used to facilitate commercial hybrid production.

Some within set testcross hybrids, e.g. L₂₅/L₂₇//L₂₇ which is a backcross hybrid gave higher yield than the recovered hybrid (L₂₅/L₂₇) and the original hybrid Agsh₂201/Agsh₂318. The result strongly supported that additive and partial dominant effect are predominantly responsible for the expression of heterosis.



Student's signature



Thesis Advisor's signature

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Nguyen Tien Truong
November 2005

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DEVELOPMENT OF SWEET CORN (*Zea mays* L.) INBRED LINES BY FAMILY SELECTION UNDER DIFFERENT COMPETITION ENVIRONMENTS

INTRODUCTION

Modern maize breeding methods are primarily a twentieth century phenomenon. Successful development of the inbred line-hybrid concept of maize to a useful form is still considered one of plant breeding's greatest achievements (Hallauer, 1988).

The pure-line method of maize (*Zea mays* L.) breeding has been the basic breeding method used in developing lines and hybrids since the suggestion of Shull in 1909. Modifications of the pure-line method of breeding have been made during the past 80 years as information, techniques, and equipments became available. However, modification of the pure-line method will continue (Hallauer, 1989).

The primary difference between field and sweet corn is altered carbohydrate composition in the endosperm, sweet corn is distinguished from other types of corn by many genes that affect all phases of plant growth. These genes affect table or eating quality (flavour, tenderness, and texture), appearance of ears and plants, and seed viability. Sweet corn is not a race of maize or a separate subspecies within the species *Zea mays* (L.). It is differentiated from other type of corn by a gene or genes that alter endosperm starch synthesis and its use as a vegetable, and much of the literature on field corn is applicable to sweet corn and should be examined for a complete view of the crop (Tracy, 2001).

An enormous amount of genetic diversity exists within the maize species (*Zea mays* L.). A vast array of phenotypic and genetic diversity evolved within the species due to the varied environments to which people throughout the thousand of years exposed maize. Major factors involved in the evolution of distinct groups referred to

as races of maize probably were mutation and natural isolation mechanisms (geographic separation, differences in time of flowering, and gametophytic factors). Isolation by human of population with unique ear and grain characteristics for special use such as in ceremonies, migration of maize with people and hybridization of formally distinct race to form new ones (Brown, 1953; Hallauer and Miranda, 1981; Well Hausen *et al.*, 1957).

The most often used plant breeding method for inbred line development in maize is the pedigree method. It emphasizes knowing the materials with complementary traits for breeding starts and keeping record that show family relationship. Moreover, all methods use the pedigree method for final development of the inbreds and the pedigree method is still the most popular breeding method for improvement of inbred (Troyer, 2001).

Sweet corn breeding, while using many of the techniques and theories developed by field corn breeders, is very different in practice because of the different end use of the variety, the effect of xenia, and the highly perishable nature of the final product. These factors directly affect methods used in evaluating inbreds and hybrids. The specific objectives, germplasm, and techniques depend upon the intended use for the new hybrid (Tracy, 2001).

Higher plant densities provide greater stress on the progenies and thus selected progenies were able to withstand stress said by Troyer and Rosenbrook (1983) and Russell (1991). In addition, they suggested that selection should be conducted under higher plant densities than normal growing condition to enhance grain yields in maize. On the contrary Fasoula (1995), and Fasoula and Fasoula (1997) proposed selection under isolation environment in honeycomb designs to avoid plant-to-plant competition, minimize soil heterogeneity, promote highest expression of genetic potential, enhance differentiation among lines and thus facilitate line selection.

Objectives

The objectives of this study were:

1. To evaluate the difference between inbred lines and their hybrid performances which were developed by family selection under different plant densities;
2. To determine the breeding method which maximize the potential of inbred lines in hybrid combination.

LITERATURE REVIEW

The objective of most sweet corn breeding programs is improved single cross hybrids, and breeders spend a large portion of their effort developing superior inbreds. Corn tolerates extreme inbreeding and most new inbreds are the result of 8 or more generations of selfing and selection. Commercially useful sweet corn inbreds must combine well with other inbreds to produce hybrids with acceptable yield, agronomic performance, processing ability, and table quality. The inbreds must be acceptable for use in commercial seed production. Inbreds used as a seed parents must produce acceptable quantities of high-quality seed, be easy to detassel, and be adapted to mechanical harvesting with good ear placement and lodging resistance. A pollen parent should shed abundant amounts of pollen for a relatively long period of time. And because pollen production may be reduced by heat stress (Westgate and Bassetti 1990), a pollen parent should tolerate high temperatures.

Genetic improvement

There are numbers of options available for genetic improvement of maize breeding such as selection, hybridization or cross breeding. The purpose of a selective breeding program is to change the average performance of a population in a defined direction. During selection, individuals or families are chosen on the basis of commercially important traits to change the population mean in the next generation. If the desired phenotype of an organism is controlled by additive genetic variance and expressed high level of heritability (h^2), the character will respond well to selection. The change produced by selection is the change of population mean. Response to selection is the difference of mean phenotypic value between the offspring of the selected parents and mean of the parental generation before selection (Falconer, 1989).

There are several approaches for selection including mass selection, family selection and within family selection (Falconer, 1989). Each has its own merit

depending on the nature of the characters to be selected and the resources available for the selection program. Mass selection or individual selection involves the selection of individuals on the basis of their value of commercially important traits. Individual or mass selection can be efficiently applied when traits are mainly influenced by additive genetic variance (high h^2 value). When the character selected has a low heritability (less than 0.2) family mean is taken into account and the whole family is considered as a single unit for selection. Within family selection has an advantage of environmental variance common to all family members and thus would eliminate large non-genetic component of variation (Tave, 1995).

Modified ear-to-row and modified S_1 selection methods involve selection at two levels: among family selection and within family selection. The genetic gain per cycle of a method is equal to the sum of the gains due to among family selection and within family selection (Empig *et al.*, 1972; Utz, 1984; Hallauer and Miranda, 1988; Dhillon and Khehra, 1989).

Selfing was the first used in recurrent selection system to maintain tested genotypes. It has been shown that variability among families increases with inbreeding so use of inbred families in a recurrent selection system is mainly for characters of low heritability (Hallauer and Miranda, 1981).

The theoretical basis for population development has been given, and a variety of procedures is available for the improvement of maize (Hallauer, 1981). This work is applicable to both field corn and sweet corn. Synthetic populations in sweet corn have been built around (a) elite inbreds of related origin, (b) adapted hybrids, (c) incorporation of disease and insect resistance, and (d) emphasis on quality, earliness, yield potential, row number, colour enhancement, mutant endosperms, and other characters. With recurrent selection, the next cycle of selection may be initiated immediately after the first intercrossing among selected parents, but the choice of an appropriate tester and procedure will vary, depending upon objectives associated with each population. In every case, however, simultaneous selection must be exercised for

yield and desired horticultural characteristics, as well as for quality attributes (Kaukis and Davis, 1986)

Patterns of response to recurrent selection also are indicative of the type of gene action controlling a trait. The selection for general combining ability (GCA) that dominate favourable genes are important in heterosis, and the selection for specific combining ability (SCA) that over dominance and epistasis are mainly responsible for heterosis (Sprague and Miller, 1950)

Recurrent selection is commonly used to improve population of maize (*Zea mays* L.). The populations improved by recurrent selection are used directly as open-pollinated cultivars, non-inbred progenitors of non-conventional hybrids and as source of germplasm to derive inbred lines. The modified ear-to-row selection was used with the selection intensities of 50 to 60% for among family selection and 6 to 18% for within-family selections (Vasal *et al.*, 1997)

Smith (1983) concluded that recurrent selection was effective for increasing grain yield and improving other agronomic characters in population crosses. However, effects of drift due to small population size were evident in the population per se. Smith (1983) wrote on his conclusion if the heritability of seed yield was sufficient high, faster progress might be made using phenotypic recurrent selection, particularly if it could be applied annually.

Several widely used elite lines have been derived from populations improved by recurrent selection. Recurrent selection employs genetically broad-based populations and gradually increases the frequency of favourable alleles (Hallauer, 1985). A large body of empirically derived knowledge has accumulate on quantitative genetic and phenotypic responses to various types of recurrent selection (Hallauer and Miranda, 1988), however, variation in response with and among selection programs indicates a limit to our understanding of the genome's response to conscious selection. Because a single cycle of recurrent selection programs necessary long-term goals and investment of resources. An understanding of genetic components

underlying the selection response is needed to aid in the design for efficient recurrent selection breeding programs (Labate *et al.*, 1999)

Inbred line development and evaluation

The main difference between inbreds and a population is in genotypic frequencies. Gene frequencies remain constant, but genotypic frequencies change under inbreeding because inbreeding decreases the frequency of heterozygote and consequently increase the frequency of homozygous genotypes (Hallauer and Miranda, 1988).

Hallauer and Miranda (1981) indicated that most of the inbred lines used commercially have been developed by pedigree breeding. This method is very effective when the strengths and weakness of lines for specific traits are known. Inbreds derived by pedigree breeding can be introgressed into the appropriate FR (Full-sib Recurrent) or RRS (Reciprocal Recurrent Selection) in breeding population.

Progenies are developed from source populations by some form of inbreeding, with selfing is the most commonly used. Pedigree selection is extensively used in recycling of lines that have known strengths and weakness for specific traits. Pedigree developed by recycling of lines can become quite complex, but parentage control permits develop of lines to meet specific requirement (Hallauer and Miranda, 1988). Selections of pedigree techniques are described in greater detail by Harrington (1952) and Allard (1960) and used extensively in maize breeding programs (Bauman, 1981).

Determining the appropriate number of lines to retain during line development is crucial from the standpoint of allocating resources. Within each generation, genetic means of lines increased with increasing selection intensities. Retaining fewer families but evaluating a large number of plants per family resulted in more genetic gain of line per se as compared to saving a large number of smaller families. Identifying the superior lines early in the program and discarding those that are inferior could save resources. The subject of optimum selection intensity is important

from the standpoint of genetic gain, fixation of loci, and expenditure of resources in breeding programs (Shebeski (1967); Snee (1977); Yonezawa and Yamagata (1978).

Since the final product desired from recent maize breeding program is single cross hybrids, evaluation of inbred line performance *per se* and their combining ability with tester or other inbred are important. Good performance *per se* of inbred lines, i.e., high yields, are required in orders to produce single cross seed efficiently and economically. Furthermore, a high combining ability of inbred lines is required to produce good hybrid.

Breeders assume favourable correlation between plant, ear, and grain traits of the parental lines and performance in hybrid combination. Several studies have shown that correlation of an inbred trait with the same trait in the hybrid is relatively high, except for yield. Although many value of inbred traits, including yield, with hybrid yield have been positive and significant, in most instances they have been too low to be of predictive value (Hallauer et al., 1988). However, Sprague (1964), observed that correlation of inbreds with the mean of all their hybrids progeny is higher than correlation of inbreds with their specific single cross hybrids. These results show that inbred yields predicted general combining ability more accurately than they predicted specific combining ability. Lamkey and Hallauer (1986) observed that selection for high-yielding inbreds would tend to select lines that are above average for hybrid yields.

Today, with many elite sh_2 inbreds and hybrids available, pedigree breeding is the main method used to develop inbreds. Single, three-way, or double crosses of elite commercial inbreds may be the parental material. Parents are chosen with the specific breeding objective in mind. Crossing elite inbreds is best and the parents should complement one another (Tracy, 1997).

Many important traits in sweet corn are highly heritable and selection during inbreeding is important and useful. Such traits include ear appearance, plant habit, maturity, disease resistance, kernel tenderness, and flavor. Selection for certain traits,

such as flavour and tenderness, is time-consuming. The traits selected during inbreeding will vary according to the parental materials and the market objectives. If both parents are flavourful and tender it may be a waste of resources to evaluate their progenies for these traits. But, in a cross between a high quality inbred and an exotic source of disease resistance, selection for tenderness and flavour during the inbreeding process may be only way to ensure success (Tracy, 1997).

Resistances to both biotic and abiotic stresses may be selected during inbreeding. Procedures for the inoculation of most of the pathogens and insects attacking sweet corn have been developed and can be used during the inbreeding program. Although many traits may be selected during the inbreeding process, the combining ability of the new line must be evaluated at some generation. It is not clear at what generation of inbreeding most sweet corn breeders begin testcrossing. As is the case in field corn, early generation (F_3 , F_4) testing should be useful in estimating the combining ability of new lines (Bauman, 1981). However, two factors in sweet corn point toward the advantages of testing later generations (F_5 , F_6). Uniformity of the hybrid is of even greater importance in sweet corn than it is in field corn. Hybrids made with early generation lines would be less uniform and more difficult to evaluate. Additionally, for many end uses of sweet corn, quality factors, which have relatively high heritabilities, are more importance than yield. Thus, many non-competitive lines could be eliminated by adding one or two generations of inbreeding and selection prior to testcrossing (Tracy, 1994).

As in any hybrid development program, the ultimate worth of an inbred line can only be based on its performance in hybrid combination. However, due to the relatively high heritability and additive nature of many of the traits important in sweet corn, selection during inbreeding can be effective and important. Selection for traits, such as flavour, texture, tenderness, ear shape, row number and configuration, kernel shape and color, and husk appearance and protection, can be effective during inbreeding. Inbred performance for traits strongly affected by heterosis, including yield parameters, must be determined in test crosses.

Shull (1952) coined the term heterosis. He defined the heterosis concept as “The interpretation of increased vigor such as size, fruitfulness, speed of development, resistance to disease and to insect pests, or to climatic rigor of any kind, manifested by crossbred organisms as compared with corresponding inbred, as the specific results unlikeness in the constitutions of the uniting partial gametes”. Lamkey and Edwards (1999) wrote on their opinion, this definition is often interpreted as not implying a genetic basis for heterosis, because the definition basically describes the phenotype that results from crossing two different inbred lines.

Since pioneer contribution of Shull (1908), it has been well known that single cross hybrids are the best way to use heterosis. However, one of the limiting factors in the development of commercial single cross hybrids is the female parent because it determines the cost of seed production. Then it is necessary to select a female parent that has simultaneously a good combining ability with a male parent and a high seed yield.

Duvick (1999) stated that although the inbred-hybrid yield correlations were positive and indicated a tendency for high yielding inbreds to produce high yielding hybrids. The low value of the correlation indicated that it was not high enough to warrant selecting inbred on the basis of their yield per se; performance in crosses was and still is essential for evaluating the worth of an inbred for yield in hybrids.

To some, the term hybrid and heterosis are synonymous. This is misleading, however, because there are hybrids that do not exhibit heterosis, but there can not be heterosis without hybrid. In some species, hybrids are sold commercially because crossing of two varieties brings together complimentary traits controlled by additive gene action. Distinguishing between hybrids and heterosis is important, because hybrids bring factors other than heterosis per se i.e. uniformity to crop production. Often these factors are confounded and difficult to separate. For example, uniformity may result in higher yields. Is uniformity a genetic or nongenetic cause of increased yield? Is uniformity a factor in heterosis? (Lamkey and Edwards 1999).

Falconer and Mackay (1996) defined heterosis or hybrid vigor as the difference between the hybrid and the mean of the two parents. Lamkey and Edwards (1999) said that this definition is usually called mid parent heterosis. Mid parent heterosis is often expressed as a percentage of mid parents in the literature. It is important to note, however, that percentage mid parent heterosis is difficult to interpret from a quantitative genetic point of view, and statistical tests of percentage mid parent heterosis are nearly impossible. High parent heterosis is preferred in some circumstances, particularly in self-pollinated crops, for which the goal is to find a better hybrid than either of the parents.

Since the introduction of the sugary hybrid 'Redgreen' in 1924, most new sweet corn cultivars have been single cross hybrids (Jones and Singleton 1934; Kaukis and Davis, 1986). Due to the strong demand for uniformity of ear type and harvest maturity by sweet corn processors, single cross hybrids were used much earlier than in field corn. Occasionally, modified single crosses are used commercially. The seed parent of a modified single cross is the F_1 between two closely related inbreds (sister lines). The sister line cross is then crossed to an unrelated inbred as the pollinator. A modified single cross has increased seed yields and seedling vigor, but still has acceptable uniformity.

Backcross breeding is widely used in sweet corn improvement to transfer endosperm starch synthesis and color alleles into elite inbreds. It is also used to incorporate single gene disease resistances and transgenes. Typically, initial development of varieties based on new endosperm mutants has been backcrossing the new gene into elite *su1* inbreds, usually into both parents of an established cross. The *su1* allele is usually selected against during backcrossing. Backcrossing endosperm mutants into elite inbreds can be rapid and efficient. By selfing the backcross generation to detect the presence of the desired allele, and simultaneously crossing into recurrent parent, only one season per backcross cycle is required. But, expression of endosperm genes is affected by inbred background, and simple backcrossing with no selection may result in new lines with either poor germination or undesirable

flavour. Therefore, selection should be performed during backcrossing to ensure acceptable performance of the new inbred (Tracy, 2001).

Roles of plant densities

Donald and Hamblin (1976) distinguished three simple ecosystems in which genotypes are grown by plant breeders: spaced plants, plants within a mixed community of genotypes, and plants in a dense monoculture, a crop. They suggested further that it might be useful in plant breeding practice to divide ecosystems into three major categories: (1) isolation environments, where widely spaced plants exclude plant-to-plant interference, (2) competition environments, composed of interactions between genetically dissimilar genotypes, and (3) crop environments, composed of interactions between genetically identical genotypes.

According to Yan and Wallace (1995), the crop yield potential of a genotype consists of two components: potential yield per plant, measured in the isolation environment, and tolerance to density. This is shown by their equation $Y_{\max} = (1/4) a^2 b^{-1}$, where the crop yield potential of a given genotype (Y_{\max}) is expressed as the product of the square of the single plant yield potential in the absence of competition (a^2), multiplied by the genotype's tolerance to plant density (b^{-1}).

Duvick (1997) focused attention to the importance of potential yield per plant of maize hybrid in low stress environments, as a means of improving the crop yield potential. In addition, he arrived at this conclusion after studying the response to plant density of maize hybrids during past 70 years and after finding out that, the potential yield per plant (1 plant/m²) of maize hybrids remained unchanged.

At high plant densities, yield per unit area was maximal on account of superior exploitation of the available resources, but the yield differentiation among cultivars was reduced to almost zero. This implies that even if breeders were in a position to mimic the conditions of dense monoculture for every individual genotype during the early segregating generations, the reduced differentiation in dense stand would impair

response to selection. On the contrary, at low plant densities, representing absence of competition, exploitation of the available resources was minimal and yield differentiation was maximal (Fasoula and Fasoula, 1997).

Fasoulas and Fasoula (1995), and Fasoula and Fasoula (1997) proposed selection under isolation environment in honeycomb designs to avoid plant-to-plant competition, minimize soil heterogeneity, promote highest expression of genetic potential, enhance differentiation among lines and thus facilitate line selection. Apparently, the maximization of phenotypic differentiation through increased plant spacing erases the disturbing effects of density and competition that prove to be larger than the disturbing effects of soil heterogeneity. Furthermore, Duvick (1997) also suggested that the best way to effect future gains in yielding ability may be to make further improvements in tolerance to high plant densities, in combination with improvements in potential yield per plant under low stress environments.

Fasoula and Fasoula (1997) conclude about the effect of competitive ability on the productivity of both the crop and the competition environments may be condensed as follows: Yield per unit area in dense stands is maximized under one condition: when the interference among the plants exclusive use of the limited resources is reduced to zero. The inverse relationship found between yields of cultivars grown in pure and mixed culture results from the negative relationship between yielding and competitive ability. This has at least four implications: (1) it prevents yield maximization in the competition environment; (2) it renders the competition environment unfit for selection; (3) it limits the use of heterozygous and heterogeneous population as potential cultivars; and (4) it establishes that evolution via interplant competition by natural selection favors competitive ability at the expense of yielding ability.

Tollenaar (1991) demonstrated that the higher tolerance of the new maize hybrids to plant density stress is associated with the general improvement in tolerance to the different stresses that contribute to uniform growth. Apparently, improving tolerance to environmental stresses constitutes a safe way to ensure tolerance to

increasing plant density as well. Increased plant densities are not only indispensable for attaining maximal yields, but as pointed out by Fery and Janick (1970); they also facilitate mechanical harvest through early and concentrated yield.

Kyriakou and Fasoulas (1985) concluded that the impact on response selection of the recognized negative correlation between yielding and competitive ability. When this correlation is considered at the individual plant level, it means that a plant possessing genes for high yield potential will possess genes for low competitive ability vice versa, a plant possessing genes for low yield potential will possess genes for high competitive ability. This implies that response to selection for yield of individual plants is effective in the isolation environment, but ineffective in the competition environment.

Furthermore, Fasoula and Fasoula (1997b) analyzed the crop yield potential of a genotype into three components: (a) potential yield per plant, measured by the entry mean (\bar{X}), (b) tolerance to stresses, predicted by the standardized entry mean (\bar{X}/δ_p), which represents the reverse value of the coefficient of variation (CV) and (c) responsiveness to inputs, predicted by the standardized selection differential ($\bar{X}_s - \bar{X}$)/ δ_p . All parameters were measured under isolation environment in honeycomb design.

According to Fasoula and Fasoula (1997a), under nil-competition, the mean \bar{X} and its standard deviation δ_p increase, but the \bar{X} increases at a higher rate than the δ_p , resulting in decreased CV, the impact is that the single plant heritability is optimized in the absence of competition where the phenotypic expression and differentiation are maximized, and that heritability is improved by increasing the share of genetic variance at the expense of environmental variance. On the other hand, under competition, the negative correlation between yielding and competitive ability erases the correspondence between genotypic and phenotypic values.

Fasoulas (1999) concluded that the main effect of efficient recycling is the replacement of deleterious genes by favorable additive alleles that increase the yield and stability of inbreds, and transmit their favorable effects to the hybrids. His general conclusion was that the best way to eliminate deleterious genes and improve inbred line and hybrid performance is selection in the isolation environment for high potential yield per plant on the basis of the mean yield, and for stability of performance on the basis of reduced CV. Selection for combining ability early in the program leads to the preservation of deleterious genes on account of evaluation under heterozygosity. The more the evaluation of inbreds is based on combining ability, the more deleterious genes are preserved in large numbers, and the productivity gap between inbreds and hybrids remains wide. Conversely, the more deleterious genes are replaced by favorable additive alleles, the more the yielding capacity of both inbred lines and hybrids improves and the less the heterosis in F_1 (Koutsika *et al.*, 1990; Fasoula, 1993; 1997). Production of vigorous inbred lines that approach hybrid productivity is feasible only when selection is based on line performance per se, so that deleterious genes can be effectively removed and replaced by favorable additive alleles (Fasoula and Fasoula, 1997b).

Recent era maize hybrids carry a high load of deleterious genes retained by heterozygosity that is favored by selection for combining ability. This keeps the productivity gap between inbreds and hybrids very wide (Mechii *et al.*, 1984), and increases best- and mid- parent heterosis. To obtain highly productive inbreds and improve further hybrid performance, selection should be done in the absence of competition across environments, not for combining ability, but for inbred line performance per se, under enhanced gene fixation and on the basis of the component of crop yield; i.e., yield per plant (\bar{X}), tolerance to stresses (\bar{X}/δ_p), and responsiveness to inputs ($(\bar{X}_s - \bar{X})/\delta_p$). Therefore, the final few outstanding lines can be easily test in diallel crosses to isolate the best single-cross hybrids (Faloulas, 1999).

DuVick (1996) reported, “Breeding techniques today would be immediately recognizable to a breeder from 1930s. Cut-and-try is still the best genetic procedure in corn breeding.” We must develop more efficient plant breeding methods that will allow us to apply selection for yield and stability as early as in the F₂ and F₃ generations. This is critical because there is a substantial decrease in the expected frequency of higher-yielding genotypes with each generation of selfing without selection.

The honeycomb breeding adopted the following principles: (1) evaluation in the absence of interplant competition; (2) enhancement of gene fixation; (3) Increased sampling of selection sites to cover the target area of adaptation; (4) utilization of the honeycomb designs; (5) development of criteria that predict crop yield based on evaluation of single plants in the absence of competition; (6) adoption of non-stop selection (Fasoula and Fasoula, 1997).

On the grounds that desirable selection designs are those allocating entries under comparable growing condition by effectively sampling for environment variation. Fasoula (1973 and 1993) developed the honeycomb selection designs over the last three decades. The novel designs were termed honeycomb designs because of the hexagonal arrangement of plot in the field. Plots that best fit honeycomb designs are hill plots ranging from single plots to multiple plots. Although systemic in nature, honeycomb designs accomplish effective sampling for soil heterogeneity by means of large number of moving replicates.

Tokatlidis *et al.* (2001) showed on their selection study in the F₂ of the single cross maize hybrid (PR 3183) for inbred characterized by high yield per plant and high standardized mean led to recycled hybrids with equal performance to the original hybrid at higher plant densities and statistically better performance at lower plant densities. Their results showed that continuous recycling in the absence of competition for the three components of crop yield across the production environments may lead to the development of highly productive and stable inbreds that transmit their superior performance and render hybrids density-independent.

Commenting on the honeycomb arrangement of field plots, Jensen (1988) remarked that breeders must not lose sight of the fact that the honeycomb system is a serious effort to inactivate or neutralize parts of environment so that true genotypic responses might be seen. Fasoula (1995) wrote on his conclusion honeycomb designs by combining the advantage of systematic arrangement with the Fisherian principles of replication, randomization and local control, enhance the chances for success in plant breeding. For the honeycomb design, selection of plant and evaluation of better performance of genotype (high yield and other agronomic traits) are mostly done by moving circle selection. Because this moving circle selection have some advantages. Moving circle selection applied to both unreplicated and replicated materials and increases reliability as a result of at least four advantages.

1) The sum of distances separating the central plant from the others plants within the circle is minimal compared to the same number of plants in grids of other shapes.

2) Regardless of the way in which moving-circle selection is performed, either by hand or by a computer.

3) Plants are selected at all levels of soil fertility.

4) Selection pressure is adjusted by the size of the moving circle, allowing the best balance between representative sample and soil heterogeneity control.

On the contrary, higher plant densities provide greater stress on the progenies and thus selected progenies were able to withstand stress said by Troyer and Rosenbrook (1983) and Russell (1991). In addition, they suggested that selection should be conducted under higher plant densities than normal growing condition to enhance grain yields in maize. Selection under plant densities is still inconclusive and it has been an issue of discussion (Tanapong and Samphantharak, 2002).

MATERIALS AND METHODS

Materials

The seven S₆ sweet corn inbred lines and sources of germplasm were:

- 1 Agsh₂201 (derived from S₂–KSSC 941 / TSSC – 2 // TSSC – 82)
- 2 Agsh₂302 (derived from S₂-T18 / Agron 8 // Composite–S₂/TSSC–S₂–2)
- 3 Agsh₂303 (derived from S₂-T18/Agron 20//Ornamental India–S₁/TSSC–S₂–2)
- 4 Agsh₂304 (derived from S₂-T18/Agron 8 // XTRA Sweet–S₁/TSSC–S₂ – 6)
- 5 Agsh₂309 (derived from S₂-T18 / Agron 20 // Insee1 – S₂ / TSSC – S₂ -45)
- 6 Agsh₂314 (derived from S₂-T18 / Agron 8 // Sugar 73–S₁ / TSSC – S₂ – 55)
- 7 Agsh₂318 (derived from S₂-T18 / Agron 8 // Agro – S₂ / TSSC – S₂ – 2).

They were inter-crossed in diallel fashion and the derived 21 hybrids were tested for their yielding ability, quality and desirable traits in randomized complete block design with 4 replications, 3 row plots of 5 meter long with 0.75 x 0.25m plant spacing. The centre row of each plot was harvested. Top three hybrids were chosen to start this study; they were Agsh₂201 x Agsh₂309, Agsh₂303 x Agsh₂309 and Agsh₂201 x Agsh₂318.

Cultural practices

The experimental design was a RCB design with four replications per hybrid and appropriate borders to reduce the ‘edge effect’. Plots consisted of three rows, 5 m long and 0.75 m wide. Distance between plants within row was 0.25 m. The centre row was harvested at 18 days after pollination.

The whole experiments were conducted under standard cultural practices. The fertilizer was applied at the required rate of 75 kg per hectare of based nitrogen and 100 kg of P₂O₅ per hectare. Top dressing with the rate of 75 kg N per hectare was done at 6 to 8 leaf stage. Complete weed control was obtained by pre-emergence

applications of herbicides, tilling, and hand weeding. Plots were over planted and thinned to desired stands at 14 days after planting. Trials were regularly irrigated to avoid drought stress.

Statistical analysis

Analyses of variance were computed by using the MSTAT-C computer program (MSTAT-C, 1988). Yield means were compared using Duncan's multiple range tests.

Data collection

Green ear weight: The weight of ears in husk harvested from every plant in the centre row within plot. It was measured in kilogram.

Husked ear weight: The weight of husked ears harvested from every plant in the centre row within plot. It was measured in kilogram.

Cut corn weight of the sample: It was measured in kilogram of cut corn/kilogram of sample.

Recovery rate: It was measured by percentage of cut corn over green weight.

Number of marketable ears per row: present in percentage of usable ears to total husked ears.

Weight of marketable ears per hectare: present in ton ha^{-1} .

Number of unmarketable ears per row.

Weight of unmarketable ears per row.

Length of ear: Average length of ears (length of cobs) of sample. It was measured in centimetre.

Tip fill: Measurement of distance from tip where usable kernels begin to the based of ear. It was measured in centimetre.

Blank tip: Measurement of distance from tip of ear to the point where the usable kernels begin. It was measured in centimetre.

Diameter of ear: Average diameter of sample. It was measured in centimetre.

Kernel row number: Average number of kernel row of sample.

Row configuration: Straightness of rows. The rating score employ was 1 to 5 where 1 = good (completely straight), 5 = poor (zig zag row).

Ear shape: Straightness of ear, curvature (undesirable). The rating score employ was 1 to 5 where 1 = good (typical straighted shape), 5 = poor (very curvature shape).

Ear uniformity. The rating score employ was 1 to 5 where 1 = good (very uniform), 5 = poor (not uniform).

Colour of kernel: The rating score employ was 1 to 5 where 1 = brightness favourable, 5 = poor (mixed or unfavourable colour).

Depth of kernel: Average kernel depth of sample. It was measured in millimetre.

Flavour: Sweetness and aroma. The rating score employ was 1 to 5 where 1 = good (very sweet with pleasant aroma), 5 = poor (less sweet and unpleasant).

Texture: Creamy, watery or starchy. The rating score employ was 1 to 5 where 1, 2 were creamy; 3,4 were watery, 5 was starchy.

Tenderness. The rating score employ was 1 to 5 where 1 = very thin pericarp, 5 = very thick pericarp.

Sweetness: Measurement of brix level.

Days to anthesis: Days to anthesis defined as number of days from planting to 50 percent of plants in the plot shedded the pollens.

Days to silking: Days to silking defined as number of days from planting to 50 percent of plants in the plot displayed visible silk.

Plant uniformity. The rating score employ was 1 to 5 where 1 = very uniform, 5 = not uniform.

Root lodging: Root lodging was defined as the percentage of plants leaning more than 30 degrees from the vertical position in each plot.

Stalk lodging: Stalk lodging was defined as the percentage of plants with broken stalks at or below the highest ear-bearing node in each plot.

Husk cover: Length of husks beyond ear tip. The rating score employ was 1 to 5 where 1 = good protection; 5 = bad protection.

Plant height: Plant height was measured after anthesis, from the ground level to the collar of the flag leaf on 6 competitive plants.

Ear height: Ear height was measured from the ground level to the highest ear-bearing node on 6 competitive plants.

Disease resistance: Rating of resistance to downy mildews, maydis leaf blight and sheath spot. It was done when the plants were 18 – 20 days after silking. It was defined as the percentage of plants without the diseases.

Methods

Three different selection methods for inbred line development were employed; firstly, selection under high density (75 x 15 cm); secondly, selection under isolation environment in honeycomb designs with plant spacing of 0.866 m, and thirdly, selection under alternate environments of the first two methods.

Experimental seasons

Forming a diallel cross of seven selected S₆ inbred lines (Agsh₂201; Agsh₂302; Agsh₂303; Agsh₂304; Agsh₂309; Agsh₂314 and Agsh₂318) to obtain 21 hybrids.

Yield trial of the 21 hybrids were conducted and the resulted top-3 hybrids were; Agsh₂201 x Agsh₂309, Agsh₂ 303 x Agsh₂309 and Agsh₂201 x Agsh₂318, they will refered as families.

Season 1

1. The selected 3 hybrids were planted in high density (0.75 x 0.15 m). They were selfed and the top 3 ears per family were selected to form 3 inbred lines (3 S₁HD) per family.

2. The selected 3 hybrids were also planed in honeycomb (HC) design. They were selfed and the top 3 ears per family were selected to form 3 inbred lines (3 S₁HC) per family.

Season 2

1. The S₁HD were continuously planted in high density, ear-to-row and selfed. Evaluation of kernel quality was done 20 days after pollination. The top 3 ears per row were selected and bulked within row to form 3 S₂HD inbred lines per family.

2. Each ear of S₁HC was divided into two parts. One part was planted in high density, ear-to-row and selfed. Evaluation of kernel quality was done 20 days after pollination. The top 3 ears per row were selected and bulked within row to form 3 S₂HC/HD inbred lines per family.

3. The second part of S₁HC was planted in honeycomb design, ear-to-row and selfed. Evaluation of kernel quality was done 20 days after pollination. The top 3 ears per row were selected and bulked within row to form 3 S₂HC inbred lines per family.

Season 3

The processes in season 2 were repeated to obtain 3 S₃HD, 3 S₃HC/HD/HC and 3 S₃HC inbred lines per family.

- S₃HD derived from hybrid Agsh₂201/Agsh₂309 were designated as L₁, L₂ and L₃.

- S₃HD derived from hybrid Agsh₂303/Agsh₂309 were designated as L₄, L₅ and L₆.

- S₃HD derived from hybrid Agsh₂201/Agsh₂318 were designated as L₇, L₈ and L₉.

- S₃HC/HD/HC derived from hybrid Agsh₂201/Agsh₂309 were designated as L₁₀, L₁₁, and L₁₂.

- S₃HC/HD/HC derived from hybrid Agsh₂303/Agsh₂309 were designated as L₁₃, L₁₄ and L₁₅.

- S₃HC/HD/HC derived from hybrid Agsh₂201/Agsh₂318 were designated as L₁₆, L₁₇ and L₁₈.

- S₃HC derived from hybrid Agsh₂201/Agsh₂309 were designated as L₁₉, L₂₀ and L₂₁.

- S₃HC derived from hybrid Agsh₂303/Agsh₂309 were designated as L₂₂, L₂₃ and L₂₄.

- S₃HC derived from hybrid Agsh₂201/Agsh₂318 were designated as L₂₅, L₂₆ and L₂₇.

Season 4

1. The same method as used in season 3 was employed to obtain 3 S₄HD, 3 S₄HC/HD/HC/HD and 3 S₄HC.

2. S₃HD was planted in honeycomb design and the 3 S₃HD within each family were diallel crossed to obtain L₁/L₂, L₁/L₃ and L₂/L₃ from family Agsh₂201/Agsh₂309; L₄/L₅, L₄/L₆ and L₅/L₆ from family Agsh₂303/Agsh₂309; L₇/L₈, L₇/L₉ and L₈/L₉ from family Agsh₂201/Agsh₂318.

3. S₃HC/HD/HC was planted in honeycomb design and the 3 S₃HC/HD/HC within each family were diallel crossed to obtain L₁₀/L₁₁, L₁₀/L₁₂ and L₁₁/L₁₂ from family Agsh₂201/Agsh₂309; L₁₃/L₁₄, L₁₃/L₁₅ and L₁₄/L₁₅ from family Agsh₂303/Agsh₂309; L₁₆/L₁₇, L₁₆/L₁₈ and L₁₇/L₁₈ from family Agsh₂201/Agsh₂318.

4. S₃HC was planted in honeycomb design and the 3 S₃HC within each family were diallel crossed to obtain L₁₉/L₂₀, L₁₉/L₂₁ and L₂₀/L₂₁ from family Agsh₂201/Agsh₂309; L₂₂/L₂₃, L₂₂/L₂₄ and L₂₃/L₂₄ from family Agsh₂303/Agsh₂309; L₂₅/L₂₆, L₂₅/L₂₇ and L₂₆/L₂₇ from family Agsh₂201/Agsh₂318.

5. Insee2, the commercial hybrid was used as tester and crossed to the 27 inbred lines, using Insee2 as the seed parent.

Season 5

1. Yield trial of the 27 intra-set hybrids was planted in normal density (0.75 x 0.25 m).

2. Yield trial of the 27 testcross hybrids was planted in normal density (0.75 x 0.25 m).

3. Yield trial of the 27 S₄ inbred lines was planted in normal density (0.75 x 0.25 m).

4. The best intra-set hybrids of each set was selected by visual selection and crossed to the 3 inbred lines of the same family to obtain:

9 intra-set testcross hybrids from 9 S₄HD; L₁/L₃//L₁, L₁/L₃//L₂, L₁/L₃//L₃, L₄/L₅//L₄, L₄/L₅//L₅, L₄/L₅//L₆, L₇/L₉//L₇, L₇/L₉//L₈, L₇/L₉//L₉.

9 intra-set testcross hybrids from 9 S₄HC; L₁₉/L₂₀//L₁₉, L₁₉/L₂₀//L₂₀, L₁₉/L₂₀//L₂₁, L₂₂/L₂₄//L₂₂, L₂₂/L₂₄//L₂₃, L₂₂/L₂₄//L₂₄, L₂₅/L₂₆//L₂₅, L₂₅/L₂₆//L₂₆, L₂₅/L₂₆//L₂₇.

9 intra-set testcross hybrids from 9 S₄HC/HD/HC/HD; L₁₀/L₁₁//L₁₀, L₁₀/L₁₁//L₁₁, L₁₀/L₁₁//L₁₂, L₁₄/L₁₅//L₁₃, L₁₄/L₁₅//L₁₄, L₁₄/L₁₅//L₁₅, L₁₇/L₁₈//L₁₆, L₁₇/L₁₈//L₁₇, L₁₇/L₁₈//L₁₈.

5. The 9 best intra-set hybrids derived from visual selection were also intercrossed to form all possible 36 inter-set hybrids.

Season 6

1. Yield trial of 27 Intra-set testcross hybrids.
2. Yield trial of 36 Inter-set hybrids.

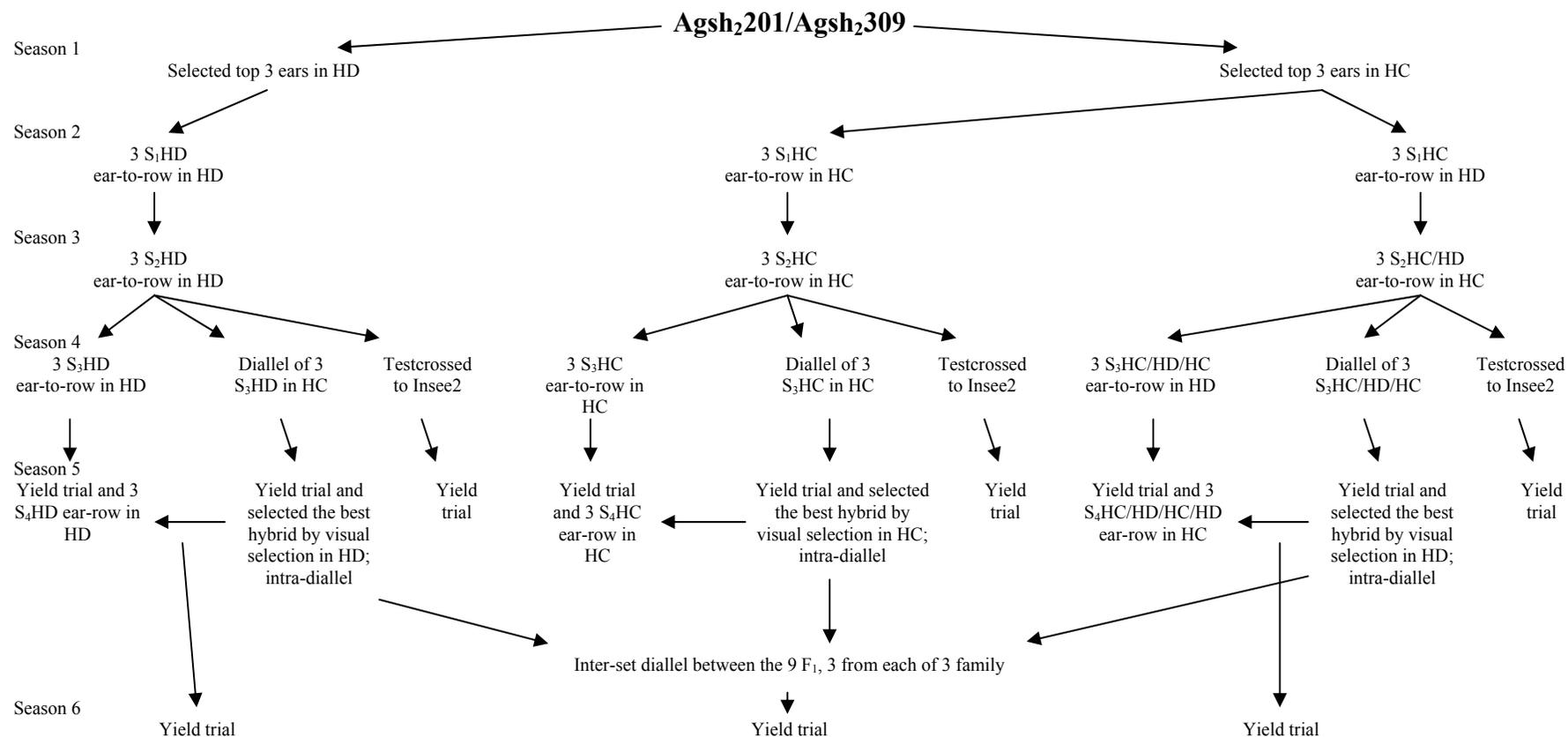


Figure 1. Breeding scheme for inbred selection of each original family

5.1 Yield trial of the 27 S₄ lines; the 27 intra-set hybrids and the 27 testcross hybrids, separately

5.2 Best derived hybrid testcross to 3 ear-row of each group

5.3 Inter-set diallel (3 sets from original 3 hybrids) of 9 best derived hybrids

6.1 Yield trial of intra-family testcross hybrids (27 hybrids)

6.2 Yield trial of inter-family hybrids (36 hybrids)

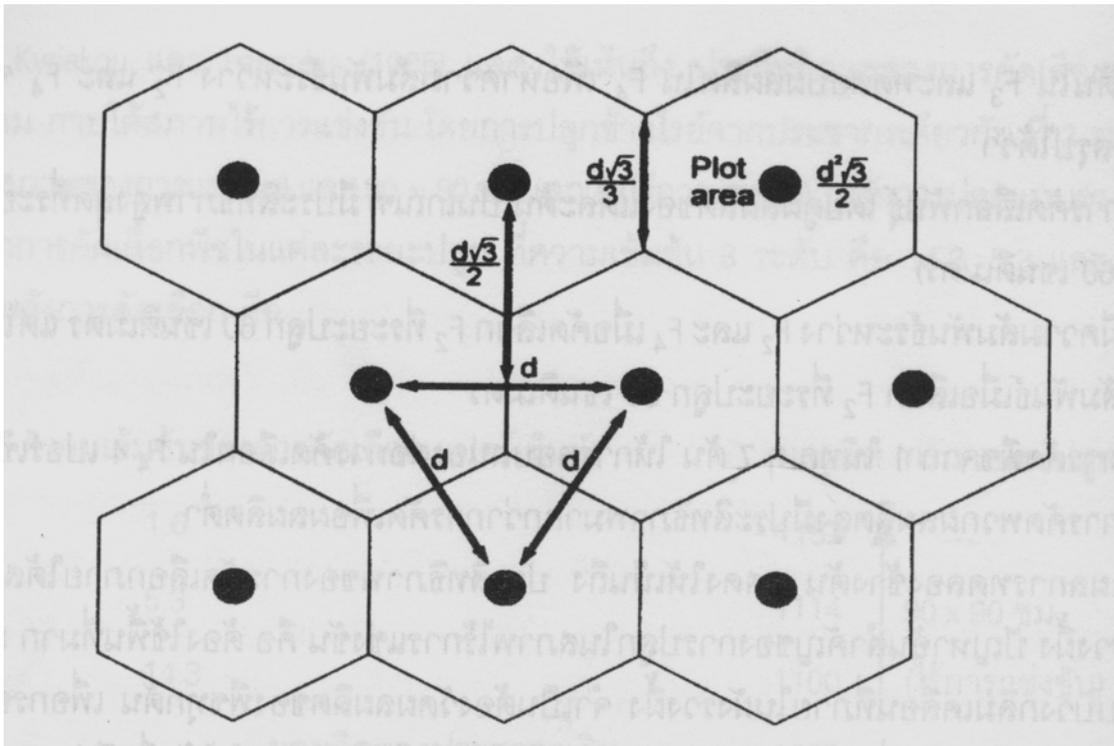


Figure 2 Honeycomb arrangement

Source: Fasoulas and Fasoula, 1995

In the figure 2, the position of hill plots is represented by the black dots. If d is the interplot distance, the distance between two rows is the height of the triangle which is equal to $0.866d$. Two-thirds of the height [i.e., $0.866d \times 2/3 = 0.577d$] is the side of each hexagon and $0.866d^2$ is the plot area that each hexagon occupies.

RESULTS AND DISCUSSION

1. Intra-set diallel yield trial

Three single-cross hybrids; Agsh₂201/Agsh₂309, Agsh₂303/Agsh₂309 and Agsh₂201/Agsh₂318 were used for inbred extraction. They were 3 leading sweet corn hybrids of Agronomy Department, Kasetsart University program. Three methods of inbred line selection were; firstly, line selection under high plant density (0.75 x 0.15 m) and designated as line numbers L₁ to L₉; secondly, line selection under isolation environment in non-replicated honeycomb design with plant spacing 0.866 m as described by Fasoulas and Fasoula (1995) and designated as line numbers L₁₉ to L₂₇, and thirdly, line selection under alternate environments between the first 2 methods and designated as line numbers L₁₀ to L₁₈. Each of 3 S₃ line set of each family was derived from each of 3 selection methods. The resulted 9 sets of S₃ composed of 27 S₃ lines, they were planted in a non-replicated honeycomb design under nil-competition environment and 3 selected plants within each set were diallel crossed to obtain 27 intra-set hybrids (3 hybrids from 3 lines of each set, 3 set per family, and total of 3 families). Green and husked ear yield and related traits of the 27 intra-set and three original hybrids Agsh₂201/Agsh₂309, Agsh₂303/Agsh₂309 and Agsh₂201/Agsh₂318 were presented in Table 1. The green ear yields of the 27 intra-set hybrids were significantly different and ranged from 8.73 to 17.07 tons ha⁻¹. The top hybrid, L₂₅/L₂₇, was also significantly higher yield than the original hybrid, Agsh₂201/Agsh₂318 and somewhat better than the other two check hybrids, Agsh₂201/Agsh₂309, Agsh₂303/Agsh₂309 although it was not significant difference. However, disease outbreak during the experimental period might hide the ability of high yield but susceptible hybrids especially germplasm involving Agsh₂303 and Agsh₂309. The results revealed that from each original germplasm, the mean yields as well as the top green ear yield of intra-set hybrids (L₁₉/L₂₀ and L₂₅/L₂₇) were highest where hybrids came from inbred lines extracted either under nil-competition environment in honeycomb design or alternate environment (L₁₃/L₁₅) and none came from selection under high density. In general, there is no correlation between high

yield inbreds and high yield hybrids although the best L₂₅/L₂₇ derived from high yield inbreds.

Husked ear yields of the 27 intra-set hybrids were also presented in the Table 1. The highest husked ear yield hybrid was also the L₂₅/L₂₇ with 10.09 tons ha⁻¹ but it was significantly lower yield than the check hybrids, Agsh₂201/Agsh₂309 and Agsh₂303/Agsh₂309. However, its yield was higher although not significant difference from its original hybrid, Agsh₂201/Agsh₂318. The results revealed that the high green ear yield hybrid tended to give high husked ear yield of the same origin. The advantage of each selection method over the hybrid yields was not clear. However, yield of inbreds selected under wide space (honeycomb) were clearly superior than inbreds from the other two methods (Table 3)

Besides husked ear yield, percentage of recovery is also the important yield parameter for whole kernel and cream-style corns. This was determined by ratio of cut corn over the green corn weight. The kernel yield depended upon kernel depth and kernel row number. The recovery rate of the 27 intra-set hybrids were presented in Table 1 where recovery percentage of each hybrid within each family was not different regardless of selection method. Fasoula and Fasoula (1997a) cited evidences that single plant heritability is optimized in the absence of competition where the phenotypic expression and differentiation are maximized, and that heritability is improved by increasing the share of genetic variance at the expense of environmental variance. On the other hand, under competition, the negative correlation between yielding and competitive ability erases the correspondence between genotypic and phenotypic values. Tokatlidis *et al.* (1998) showed that selection under nil-competition environment not only gave higher yield recycled inbreds but also higher yield recycled hybrids. However, several studies indicated that correlation between high yield inbreds and their corresponding hybrids were very low and can not be used for hybrid yield prediction.

Ear length, tip fill and blank tip of each intra-set hybrids were ranged from 16.4-20.0, 13.6-17.7 and 1.4-3.7 cm, respectively as compared to 20.3, 18.0, 2.3; 18.7,

16.9, 1.8 and 18.4, 16.3, 1.8 cm for the three traits of the check hybrids, Agsh₂201/Agsh₂309, Agsh₂303/Agsh₂309 and Agsh₂201/Agsh₂318, respectively. Ear diameter was ranged from 3.65 to 4.42 cm which was in the similar range of their original hybrids. Kernel row number of all intra-set as well as the check hybrids were relatively low and ranged from 12.5 to 15.2. The desirable kernel row number for processed sweet corn hybrid should be more than 16. Tenderness and sweetness of each intra-set hybrid were more or less similar to their original hybrids, but they were in the acceptable ranges for commercial sweet corn hybrid.

Table 1 Green and husked ear yield, percentage of marketable ears, husked ear yield and recovery of intra-set hybrids (S₃ x S₃), planted at Suwan Farm, Thailand in January, 2005 (dry season).

	Parent were extracted from Agsh2-201/309						Parent were extracted from Agsh2-303/309						Parent were extracted from Agsh2-201/318					
	Hybrid	Green ear yield (ton/ha)	Husked ear yield (ton/ha)	% marketable ears	% husked ear yield	Recovery (%)	Hybrid	Green ear yield (ton/ha)	Husked ear yield (ton/ha)	% marketable ears	% husked ear yield	Recovery (%)	Hybrid	Green ear yield (ton/ha)	Husked ear yield (ton/ha)	% marketable ears	% husked ear yield	Recovery (%)
HD	L ₁ /L ₂	8.73 ^{k*}	4.47 ^h	65.77 ^h	51.67 ^e	26.88 ^{h-i}	L ₄ /L ₅	10.47 ^{g-k}	7.46 ^f	88.99 ^{a-e}	71.43 ^{a-b}	43.68 ^{a-d}	L ₇ /L ₈	14.27 ^{bc}	9.63 ^{bc}	88.98 ^{a-e}	67.49 ^{a-d}	36.82 ^{a-i}
	L ₁ /L ₃	12.27 ^{c-g}	8.08 ^{d-f}	85.90 ^{a-f}	66.15 ^{a-e}	34.51 ^{c-i}	L ₄ /L ₆	11.20 ^{d-j}	7.34 ^f	87.64 ^{a-e}	66.56 ^{a-d}	41.43 ^{a-e}	L ₇ /L ₉	13.33 ^{cd}	8.49 ^{c-f}	87.18 ^{a-f}	63.69 ^{a-e}	35.29 ^{b-i}
	L ₂ /L ₃	10.57 ^{f-k}	7.29 ^f	88.92 ^{a-e}	69.36 ^{a-c}	36.43 ^{a-i}	L ₅ /L ₆	11.40 ^{d-j}	7.70 ^{ef}	87.15 ^{a-f}	68.55 ^{a-d}	43.51 ^{a-d}	L ₈ /L ₉	13.40 ^{cd}	7.92 ^{ef}	80.11 ^{c-g}	59.77 ^{a-e}	33.95 ^{c-i}
	Average	10.52	6.61	80.19	62.39	32.61	Average	11.02	7.50	87.92	68.85	42.87	Average	13.67	8.68	85.42	63.65	35.35
HC	L ₁₉ /L ₂₀	13.02 ^{c-f}	9.27 ^{b-d}	90.90 ^{a-d}	72.03 ^a	39.64 ^{a-g}	L ₂₂ /L ₂₃	11.60 ^{d-i}	8.43 ^{d-f}	96.54 ^{a-b}	73.74 ^a	47.36 ^{a-b}	L ₂₅ /L ₂₆	12.93 ^{c-g}	8.71 ^{c-e}	84.83 ^{a-f}	67.40 ^{a-d}	34.00 ^{c-i}
	L ₁₉ /L ₂₁	10.73 ^{e-k}	7.87 ^{ef}	85.43 ^{a-f}	73.79 ^a	41.90 ^{a-d}	L ₂₂ /L ₂₄	11.48 ^{d-i}	8.28 ^{d-f}	98.81 ^a	72.52 ^a	48.37 ^a	L ₂₅ /L ₂₇	17.07 ^a	10.09 ^b	87.08 ^{a-f}	59.41 ^{a-e}	31.66 ^{d-i}
	L ₂₀ /L ₂₁	9.33 ^{i-k}	4.99 ^{gh}	73.59 ^{f-h}	55.02 ^{c-e}	27.89 ^{g-i}	L ₂₃ /L ₂₄	10.70 ^{e-k}	7.66 ^{ef}	93.60 ^{a-c}	72.52 ^a	45.81 ^{a-c}	L ₂₆ /L ₂₇	12.67 ^{c-g}	8.21 ^{d-f}	83.81 ^{b-f}	65.64 ^{a-e}	35.25 ^{b-i}
	Average	11.01	7.38	83.31	66.95	36.48	Average	11.26	8.12	96.32	72.93	47.18	Average	14.22	9.00	85.24	64.15	33.63
Alter	L ₁₀ /L ₁₁	11.27 ^{d-j}	6.03 ^g	68.16 ^{g-h}	54.05 ^{d-e}	28.55 ^{f-i}	L ₁₃ /L ₁₄	10.81 ^{e-k}	7.85 ^{ef}	93.01 ^{a-c}	73.48 ^a	44.31 ^{a-c}	L ₁₆ /L ₁₇	8.99 ^{lk}	6.09 ^g	78.18 ^{d-h}	68.59 ^{a-d}	34.17 ^{c-i}
	L ₁₀ /L ₁₂	11.86 ^{c-h}	8.36 ^{d-f}	92.11 ^{a-d}	71.12 ^{a-b}	40.63 ^{a-f}	L ₁₃ /L ₁₅	13.20 ^{c-e}	8.74 ^{c-e}	91.04 ^{a-d}	66.96 ^{a-d}	38.86 ^{a-h}	L ₁₆ /L ₁₈	13.20 ^{c-e}	7.37 ^f	75.22 ^{e-h}	56.35 ^{b-e}	29.24 ^{e-i}
	L ₁₁ /L ₁₂	9.73 ^{h-k}	4.99 ^{gh}	69.98 ^{g-h}	51.41 ^c	26.44 ⁱ	L ₁₄ /L ₁₅	12.34 ^{c-g}	8.35 ^{d-f}	92.88 ^{a-c}	69.00 ^{a-d}	43.24 ^{a-d}	L ₁₇ /L ₁₈	12.60 ^{c-g}	8.01 ^{ef}	89.85 ^{a-d}	64.39 ^{a-e}	34.82 ^{c-i}
	Average	10.95	6.46	76.75	58.86	31.87	Average	12.12	8.31	92.31	69.81	42.14	Average	11.60	7.16	81.09	63.11	32.74
Origin hybrids	Agsh ₂ -201/309	16.13 ^{ab}	11.39 ^a	95.00 ^{a-b}	70.11 ^{a-c}	39.89 ^{a-g}	Agsh ₂ -303/309	16.20 ^{ab}	11.49 ^a	97.50 ^{a-b}	70.43 ^{a-b}	43.48 ^{a-d}	Agsh ₂ -201/318	13.07 ^{c-e}	9.25 ^{b-d}	96.30 ^{a-b}	70.80 ^{a-b}	37.74 ^{a-i}

* Means within a column followed by the same letter are not significantly different at P≤0.05 according to Duncan's multiple range test.

Table 2 Some agronomic and quality traits for commercial sweet corn of intra-set hybrids ($S_3 \times S_3$), planted at Suwan Farm, Thailand in January, 2005 (dry season).

Rank Order ^{1/}	Hybrid	Ear length	Tip fill	Blank tip	Diameter	Kernel depth	Kernel row	Tenderness	Sweetness
		cm						1-5 ^{2/}	%
1	L ₁ / L ₂	16.5	14.5	1.9	3.92	0.73	14.2	2.0	13.45
2	L ₁ / L ₃	17.8	16.4	1.4	3.88	0.75	14.5	2.0	13.90
3	L ₂ / L ₃	18.1	16.0	2.1	4.01	0.87	14.8	2.0	13.35
4	L ₄ / L ₅	17.1	15.1	2.0	4.08	0.91	14.2	1.5	13.55
5	L ₄ / L ₆	17.6	15.5	2.1	3.95	0.83	14.2	1.5	14.25
6	L ₅ / L ₆	16.9	14.3	2.5	3.99	0.89	14.3	1.5	13.70
7	L ₇ / L ₈	19.0	17.6	1.4	4.11	0.83	13.9	2.5	14.50
8	L ₇ / L ₉	17.9	16.5	1.5	4.15	0.89	14.3	2.5	14.55
9	L ₈ / L ₉	18.0	16.4	1.6	4.10	0.92	14.2	2.5	14.40
10	L ₁₀ / L ₁₁	18.4	16.1	2.3	3.88	0.77	14.3	2.0	15.05
11	L ₁₀ / L ₁₂	18.1	16.0	2.1	3.85	0.85	13.6	2.0	14.40
12	L ₁₁ / L ₁₂	16.4	13.6	2.8	3.65	0.65	13.8	1.5	14.50
13	L ₁₃ / L ₁₄	16.9	13.7	3.2	4.07	0.95	13.6	1.5	14.45
14	L ₁₃ / L ₁₅	17.5	13.7	3.7	4.42	0.97	15.1	2.0	14.90
15	L ₁₄ / L ₁₅	17.4	14.8	2.6	4.14	0.93	14.6	1.5	14.60
16	L ₁₆ / L ₁₇	17.9	16.0	1.9	3.73	0.76	12.5	2.0	14.60
17	L ₁₆ / L ₁₈	19.2	17.4	1.8	3.91	0.78	14.1	2.0	13.95
18	L ₁₇ / L ₁₈	19.1	17.3	1.8	3.83	0.80	13.6	2.5	14.15
19	L ₁₉ / L ₂₀	19.2	17.0	2.2	4.06	0.84	15.1	2.0	15.15
20	L ₁₉ / L ₂₁	19.6	17.7	1.9	4.00	0.83	14.2	1.5	14.45
21	L ₂₀ / L ₂₁	18.0	14.7	3.3	3.68	0.73	14.1	2.0	14.05
22	L ₂₂ / L ₂₃	17.0	14.8	2.1	3.87	0.94	15.2	1.5	14.25
23	L ₂₂ / L ₂₄	19.0	16.3	2.7	3.98	0.90	13.7	2.0	14.40
24	L ₂₃ / L ₂₄	17.3	15.3	2.0	3.99	0.92	13.8	2.0	15.00
25	L ₂₅ / L ₂₆	17.9	16.0	1.9	4.29	0.81	14.1	2.0	14.35
26	L ₂₅ / L ₂₇	20.0	17.7	2.3	4.24	0.85	13.9	2.0	14.85
27	L ₂₆ / L ₂₇	18.0	16.0	2.0	4.05	0.82	13.6	2.5	15.20
Check 1	Agsh ₂ -201/309	20.3	18.0	2.3	4.27	0.92	15.1	2.0	14.10
Check 2	Agsh ₂ -303/309	18.7	16.9	1.8	4.01	0.93	14.5	1.5	13.97
Check 3	Agsh ₂ -201/318	18.4	16.3	2.1	4.10	0.86	14.4	2.5	14.63
Mean		18.1	15.9	2.2	4.00	0.85	14.2		14.36
%CV		5.6	7.9	24.7	4.37	9.12	4.0		3.36

^{1/} 1-9: Hybrids were derived from HD; 10-18: hybrids were derived from alternated and 19-27 which were derived from HC.

^{2/} 1: very thin pericarp; 5: very thick pericarp; 2.5: acceptable level

2. Inbred line yield trial.

Twenty seven S_3 lines were advanced to S_4 by each of selection method. Means and ranges of the 27 S_4 inbred lines from each set across three original sources were presented in Table 3. The overall mean grain yield ranged from 0.420 tons ha^{-1} of L_{23} to 1.104 tons ha^{-1} of L_{21} while grain yield of the four original inbred lines (check) ranged from 0.532 tons ha^{-1} to 0.788 tons ha^{-1} . There were four inbred lines gave significantly higher grain yield than the best inbred check, Agsh₂201, three of them were L_{21} , L_{24} and L_{25} , which were extracted under nil-competition environment in non-replicated honeycomb design, derived from Agsh₂201/Agsh₂309, Agsh₂303/Agsh₂309 and Agsh₂201/Agsh₂318, respectively. The other one, L_{17} was extracted under alternate environments. Grain yield of top inbred lines from each family were from honeycomb selection under nil-competition environment. It was very clear that inbred lines of each family from honeycomb selection under isolation environment showed transgressive segregation over their corresponding parental lines of the original hybrid. Considering the grand mean (\bar{X}); honeycomb selection under isolation environment, alternate selection and high density selection were respectively effective methods of selection for inbred per se.

Table 3 Grain yields at 15 percent moisture of S₄ lines from 3 selection methods planted at Suwan Farm in January, 2005 (dry season).

	Inbred lines extracted from Agsh2-201/309			Inbred lines extracted from Agsh2-303/309			Inbred lines extracted from Agsh2-201/318		
	S ₄ Line	Yield (ton/ha)	Shelling percentage	S ₄ Line	Yield (ton/ha)	Shelling percentage	S ₄ Line	Yield (ton/ha)	Shelling percentage
HD	S ₄ L ₁	0.693 ^{c-g*}	52.6 ^{b-i}	S ₄ L ₄	0.815 ^{b-d}	60.0 ^{a-e}	S ₄ L ₇	0.817 ^{b-d}	56.4 ^{a-i}
	S ₄ L ₂	0.697 ^{c-g}	58.1 ^{a-h}	S ₄ L ₅	0.543 ^{h-j}	48.7 ^{e-i}	S ₄ L ₈	0.896 ^b	64.0 ^{a-c}
	S ₄ L ₃	0.550 ^{h-j}	45.9 ^{h-i}	S ₄ L ₆	0.425 ^k	49.5 ^{d-i}	S ₄ L ₉	0.840 ^{bc}	59.3 ^{a-f}
	Average	0.647	52.2	Average	0.594	52.7	Average	0.851	$\bar{X} = 0.697$ 59.9
HC	S ₄ L ₁₉	0.651 ^{f-i}	54.5 ^{a-i}	S ₄ L ₂₂	0.852 ^{bc}	61.3 ^{a-d}	S ₄ L ₂₅	1.024 ^a	51.9 ^{c-i}
	S ₄ L ₂₀	0.548 ^{h-j}	57.8 ^{a-i}	S ₄ L ₂₃	0.420 ^k	56.9 ^{a-i}	S ₄ L ₂₆	0.868 ^{bc}	54.6 ^{a-i}
	S ₄ L ₂₁	1.104 ^a	63.2 ^{a-c}	S ₄ L ₂₄	1.072 ^a	66.4 ^a	S ₄ L ₂₇	0.841 ^{bc}	55.8 ^{a-i}
	Average	0.768	58.5	Average	0.781	61.5	Average	0.911	$\bar{X} = 0.820$ 54.1
Alter	S ₄ L ₁₀	0.658 ^{f-h}	64.7 ^{a-b}	S ₄ L ₁₃	0.503 ^{jk}	46.4 ^{g-i}	S ₄ L ₁₆	0.596 ^{g-j}	45.7 ⁱ
	S ₄ L ₁₁	0.710 ^{d-g}	61.1 ^{a-d}	S ₄ L ₁₄	0.686 ^{c-g}	55.8 ^{a-i}	S ₄ L ₁₇	1.043 ^a	56.2 ^{a-i}
	S ₄ L ₁₂	0.565 ^{h-j}	58.3 ^{a-g}	S ₄ L ₁₅	0.895 ^b	54.9 ^{a-i}	S ₄ L ₁₈	0.846 ^{bc}	59.5 ^{a-f}
	Average	0.644	61.3	Average	0.695	52.4	Average	0.828	$\bar{X} = 0.722$ 53.8
Check 1	Agsh ₂ -201	0.788 ^{b-e}	61.7% ^{a-d}						
Check 2	Agsh ₂ -303	0.626 ^{f-i}	55.2% ^{a-i}						
Check 3	Agsh ₂ -309	0.532 ^{i-k}	61.1% ^{a-d}						
Check 4	Agsh ₂ -318	0.746 ^{c-f}	47.2% ^{f-i}						

* Means within a column followed by the same letter are not significantly different at P≤0.05 according to Duncan's multiple range test.

3. Testcross yield trial.

Testcross evaluation is used to determine the relative potential of corn (*Zea mays* L.) lines in a hybrid breeding program. Choice of tester is important for efficient selection among lines for their potential hybrids. Castellanos *et al.* (1998) showed that different testers identified inbred lines differently. The results reconfirmed the finding of Matzinger (1953); Hallauer and Miranda (1988). They concluded that the best tester should be inbred line or single cross if the ultimate breeding goal is single or three-way crosses, respectively. In this study, the well-known single-cross sweet corn hybrid in Thailand, Insee2 was used as tester to evaluate combining ability of the 27 inbred lines. Means and ranges of green ear and husked ear yield of testcross hybrids were presented in Table 4. There were 13 and 16 testcross hybrids which gave higher green ear yield but statistically not different from Agsh₂201/Agsh₂309 and Agsh₂303/Agsh₂309, respectively. Twenty four testcross hybrids were significantly higher green ear yield than Agsh₂201/Agsh₂318. The higher average as well as the top testcross hybrids from each original source came from inbred lines extracted under nil-competition environment in honeycomb design regardless of original parents. Means and ranges of husked ear yield and percentage of husked ear yield were also presented in Table 4. The average husked ear yield of testcross hybrids among original sources was statistically not different and ranged from 8.84 to 11.79 tons ha⁻¹, while the original hybrid husked ear yields were 7.52 to 11.34 tons ha⁻¹. Therefore, by average, all sweet corn inbred lines from all original sources yielded within range as their original sources as well as when crossed to the common tester, Insee2. Furthermore, there were 4 and 20 testcross hybrids, which gave significantly higher husked ear yield than Agsh₂201/Agsh₂309 and Agsh₂201/Agsh₂318, respectively. The higher average as well as the top testcross hybrids for husked ear yield from each original source came from inbred lines extracted under nil-competition environment in honeycomb design. They were also tended to have higher percentage of husked ear yield than hybrids from other selection methods. The advantage of selection under nil-competition in this study is not quite clear. However, Tokatlidis *et al.* (1999) argued that the main effect of efficient recycled inbred is the replacement of deleterious genes by favourable additive alleles that increase the yield and stability of inbreds,

and transmit their favourable effects to the hybrids. The best way to eliminate deleterious genes and improve inbred lines and hybrid performance is selection under the isolation environment in honeycomb design.

Marketable ear percentage of the top testcross hybrid, Insee2/L₂₃, was 97.62 percent but statistically not different from 93.98 percent of the best check hybrid, Agsh₂303/Agsh₂309. It was also statistically not different from the 2nd to the 17th ranked of top testcross hybrids. Likewise, Insee2/L₂₂ was the top testcross hybrid for recovery percentage with 46.33 percent and 12 top testcross hybrids were statistically not different from 46.30 percent of the best check hybrid, Agsh₂303/Agsh₂309. These evidences indicated that choice of germplasm seemed to be more important than selection method. This result was well agreed with the results revealed by Simic *et al.* (2003). Furthermore, higher average of marketable ears and recovery percentage as well as the top testcross hybrids came from inbred lines extracted in honeycomb design under isolation environment regardless of original parents. Average ear length, tip fill and blank tip of the 27 testcross hybrids were 19.1 cm, 17.3 cm and 1.8 cm, respectively as compared to 19.2 cm, 17.0 cm and 1.7 cm of the best check hybrid. Diameter, kernel depth and kernel row number were 4.24 cm, 0.90 cm and 14.1, respectively. Sweetness was ranged from 13.2 to 15.1 percent against 12.9 to 14.1 percent of the three check hybrids, Agsh₂201/Agsh₂309, Agsh₂303/Agsh₂309 and Agsh₂201/Agsh₂318. Tenderness was more or less in the ranged of 1 to 2, which was similar to the check hybrids. However, most of quality traits of germplasm used in this study were more or less the same and therefore each specified trait of all hybrids was very similar.

Table 4 Green and husked ear yield, percentage of marketable ear, husked ear yield and recovery of testcross hybrids (Insee 2 x S₃), planted at Suwan Farm, Thailand in January, 2005 (dry season).

Lines extracted from Agsh2-201/309						Lines extracted from Agsh2-303/309						Lines extracted from Agsh2-201/318						
Hybrid	Green ear yield (ton/ha)	Husked ear yield (ton/ha)	% marketable ears	% husked ear yield	Recovery (%)	Hybrid	Green ear yield (ton/ha)	Husked ear yield (ton/ha)	% marketable ears	% husked ear yield	Recovery (%)	Hybrid	Green ear yield (ton/ha)	Husked ear yield (ton/ha)	% marketable ears	% husked ear yield	Recovery (%)	
HD	Insee2/L ₁	15.47 ^{b-f*}	8.80 ^{h-k}	78.04 ^{g-j}	58.37 ^{c-e}	33.57 ^{d-i}	Insee2/L ₄	16.20 ^{b-f}	11.30 ^{a-e}	94.41 ^{a-d}	70.39 ^{a-c}	42.94 ^{a-c}	Insee2/L ₇	14.40 ^{d-g}	9.42 ^{f-j}	87.70 ^{a-i}	66.16 ^{a-d}	39.24 ^{a-g}
	Insee2/L ₂	18.53 ^{a-c}	11.28 ^{a-c}	87.38 ^{a-i}	60.75 ^{a-e}	33.60 ^{d-i}	Insee2/L ₅	16.73 ^{a-c}	11.94 ^{a-d}	93.61 ^{a-c}	71.86 ^a	44.11 ^{a-b}	Insee2/L ₈	15.80 ^{b-f}	8.69 ^{i-k}	76.20 ^{i-j}	55.75 ^{d-e}	33.29 ^{d-i}
	Insee2/L ₃	14.80 ^{d-f}	10.50 ^{d-g}	90.79 ^{a-g}	71.17 ^{a-b}	42.11 ^{a-d}	Insee2/L ₆	17.07 ^{a-c}	11.32 ^{a-c}	91.73 ^{a-f}	66.56 ^{a-d}	41.74 ^{a-c}	Insee2/L ₉	16.47 ^{a-f}	8.42 ^{jk}	70.50 ^j	51.50 ^c	27.89 ⁱ
	Average	16.27	10.19	85.40	63.43	36.43	Average	16.67	11.52	93.25	69.60	42.93	Average	15.56	8.84	78.13	57.80	33.47
HC	Insee2/L ₁₉	15.47 ^{b-f}	10.10 ^{e-i}	88.10 ^{a-i}	65.66 ^{a-d}	36.98 ^{b-h}	Insee2/L ₂₂	17.40 ^{a-d}	12.27 ^{a-c}	96.83 ^{a-b}	70.99 ^{a-b}	46.33 ^a	Insee2/L ₂₅	14.80 ^{d-f}	8.96 ^{g-k}	83.48 ^{e-i}	61.18 ^{a-e}	33.43 ^{d-i}
	Insee2/L ₂₀	18.93 ^{ab}	12.38 ^{ab}	93.40 ^{a-e}	65.89 ^{a-d}	39.98 ^{a-g}	Insee2/L ₂₃	15.20 ^{c-f}	10.45 ^{d-g}	97.62 ^a	68.82 ^{a-c}	43.45 ^{a-b}	Insee2/L ₂₆	18.54 ^{a-c}	11.55 ^{a-e}	93.60 ^{a-e}	62.37 ^{a-e}	34.34 ^{c-i}
	Insee2/L ₂₁	16.27 ^{b-f}	10.18 ^{e-i}	86.23 ^{a-i}	62.51 ^{a-e}	40.66 ^{a-f}	Insee2/L ₂₄	18.80 ^{ab}	12.66 ^a	92.12 ^{a-f}	68.13 ^{a-c}	40.13 ^{a-g}	Insee2/L ₂₇	20.00 ^a	12.19 ^{a-c}	89.22 ^{a-h}	61.22 ^{a-e}	36.23 ^{b-i}
	Average	16.89	10.89	89.24	64.69	39.21	Average	17.13	11.79	95.52	69.31	43.30	Average	17.78	10.90	88.76	61.59	34.67
Alter	Insee2/L ₁₀	14.93 ^{d-f}	8.98 ^{g-k}	81.34 ^{d-j}	60.59 ^{a-c}	34.41 ^{c-i}	Insee2/L ₁₃	18.54 ^{a-c}	11.25 ^{a-e}	86.97 ^{a-i}	61.73 ^{a-c}	37.56 ^{b-h}	Insee2/L ₁₆	17.53 ^{a-d}	9.53 ^{f-j}	76.59 ^{b-j}	55.20 ^{d-e}	29.49 ^{h-i}
	Insee2/L ₁₁	18.87 ^{ab}	10.29 ^{e-h}	79.80 ^{f-j}	54.90 ^{d-e}	31.76 ^{g-i}	Insee2/L ₁₄	17.34 ^{a-d}	10.88 ^{b-f}	84.49 ^{b-i}	63.55 ^{a-d}	38.30 ^{a-g}	Insee2/L ₁₇	16.54 ^{a-f}	10.80 ^{c-f}	96.03 ^{a-c}	65.78 ^{a-d}	39.49 ^{a-g}
	Insee2/L ₁₂	13.67 ^{e-g}	8.28 ^{jk}	80.97 ^{e-j}	61.42 ^{a-e}	33.13 ^{e-i}	Insee2/L ₁₅	13.13 ^{fg}	7.78 ^k	84.05 ^{b-i}	59.26 ^{b-c}	34.74 ^{c-i}	Insee2/L ₁₈	17.20 ^{a-c}	10.42 ^{d-g}	87.14 ^{a-i}	60.72 ^{a-e}	34.57 ^{c-i}
	Average	15.82	9.18	80.70	58.97	33.10	Average	16.34	9.97	85.17	61.51	36.87	Average	17.09	10.25	86.59	60.57	34.52
Origin hybrids	Agsh ₂ -201/309	16.64 ^{a-f}	10.52 ^{d-f}	87.81 ^{a-i}	63.61 ^{a-d}	36.84 ^{b-h}	Agsh ₂ -303/309	16.20 ^{b-f}	11.34 ^{a-e}	93.98 ^{a-e}	70.53 ^{a-c}	46.30 ^a	Agsh ₂ -201/318	11.34 ^g	7.52 ^k	80.05 ^{f-j}	65.21 ^{a-d}	32.61 ^{f-i}

* Means within a column followed by the same letter are not significantly different at P≤0.05 according to Duncan's multiple range test.

Table 5 Some agronomic and quality traits for commercial sweet corn of testcross hybrids (Insee2 x S₃), planted at Suwan Farm, Thailand in January, 2005 (dry season).

Rank Order ^{1/}	Hybrid	Ear length	Tip fill	Blank tip	Diameter	Kernel depth	Kernel row	Tenderness	Sweetness
		cm						1-5 ^{2/}	%
1	Insee2/L ₁	19.1	17.1	2.0	4.08	0.93	15.0	1.5	13.2
2	Insee2/L ₂	19.6	17.7	1.9	4.33	0.90	14.1	2.0	13.8
3	Insee2/L ₃	18.7	17.0	1.7	4.28	0.92	13.5	1.5	13.9
4	Insee2/L ₄	18.9	16.9	1.9	4.14	0.96	13.9	1.5	13.5
5	Insee2/L ₅	17.9	15.2	2.6	4.38	0.91	14.4	1.5	14.4
6	Insee2/L ₆	18.9	17.3	1.6	4.32	0.93	15.4	1.0	14.8
7	Insee2/L ₇	18.9	17.3	1.6	4.25	0.95	13.2	2.0	13.6
8	Insee2/L ₈	19.3	17.6	1.7	4.21	0.90	13.6	2.0	14.2
9	Insee2/L ₉	19.5	17.6	1.9	4.20	0.84	13.1	2.0	13.9
10	Insee2/L ₁₀	19.0	17.5	1.5	4.17	0.86	14.0	1.5	13.7
11	Insee2/L ₁₁	20.0	19.0	1.0	4.16	0.86	14.8	2.0	14.6
12	Insee2/L ₁₂	20.5	18.7	1.8	4.17	0.95	13.0	2.0	13.5
13	Insee2/L ₁₃	19.6	19.0	0.6	4.13	0.93	14.1	1.0	13.4
14	Insee2/L ₁₄	18.2	16.3	1.9	4.39	0.93	15.0	1.5	14.5
15	Insee2/L ₁₅	17.7	15.4	2.3	4.16	0.90	14.9	1.5	15.6
16	Insee2/L ₁₆	19.4	18.0	1.5	4.17	0.87	12.8	2.0	13.2
17	Insee2/L ₁₇	18.4	17.7	0.7	4.23	0.91	13.7	2.0	13.4
18	Insee2/L ₁₈	19.1	16.9	2.2	4.15	0.88	13.5	2.0	14.1
19	Insee2/L ₁₉	19.4	17.9	1.5	4.41	0.85	14.2	1.5	15.1
20	Insee2/L ₂₀	19.8	17.4	2.3	4.30	0.90	14.9	1.5	13.6
21	Insee2/L ₂₁	19.3	17.5	1.8	4.20	0.88	13.3	1.0	14.6
22	Insee2/L ₂₂	19.2	16.3	3.0	4.38	0.93	15.1	1.0	15.1
23	Insee2/L ₂₃	18.1	16.7	1.3	4.23	0.93	14.8	1.0	14.5
24	Insee2/L ₂₄	19.4	17.7	1.7	4.33	0.87	13.6	1.5	14.0
25	Insee2/L ₂₅	19.2	17.1	2.1	4.28	0.92	14.2	2.0	15.1
26	Insee2/L ₂₆	18.8	17.6	1.2	4.27	0.90	13.9	2.0	14.2
27	Insee2/L ₂₇	19.7	18.6	1.1	4.26	0.92	13.8	2.0	14.2
Check 1	Agsh ₂ -201/309	19.2	16.9	2.3	4.22	1.06	14.9	2.0	12.9
Check 2	Agsh ₂ -303/309	18.8	16.2	2.6	4.12	0.84	14.2	1.5	14.0
Check 3	Agsh ₂ -201/318	18.7	17.0	1.7	4.23	0.78	13.1	2.5	14.1
Mean		19.1	17.3	1.8	4.24	0.90	14.1		14.1
%CV		3.2	5.1	30.9	2.09	5.46	5.2		4.6

^{1/} 1-9: Hybrids were derived from HD; 10-18: hybrids were derived from alternated and 19-27 which were derived from HC.

^{2/} 1: very thin pericarp; 5: very thick pericarp; 2.5: acceptable level

4. Intra-set testcross hybrid yield trial.

One of the limiting factors in the development of commercial single cross sweet corn hybrid is the seed yield of the female parent because it determines the cost of seed production. Therefore, it is necessary to select a high yielding and high combining ability female line or using recovered single crosses as parents. From a theoretical point of view, Marquez-Sanchez reported that the difference between the heterosis in the recovered hybrid and the heterosis in the original hybrid may indicate the type of gene action of the loci, which determine the character under improvement. Under partial dominance the recovered hybrid will yield more than the original hybrid, with complete dominance the two hybrids will yield the same, and with overdominance the recovered hybrid will yield less than the original hybrid. To address this goal, the top intra-set or recovered single cross hybrids which presented in Table 6 were testcrossed to their corresponding S₄ line set. In doing so it is expected that each line retains some favorable complementary genes of the other line at loci which they are lacking.

Green ear yield and related traits for commercial sweet corn hybrid of the 27 intra-set testcross hybrids were presented in Table 7. The green ear yield of 27 intra-set testcross hybrids were significantly different and the top hybrid was L₂₅/L₂₇//L₂₇ (15.07 ton ha⁻¹). The top hybrid was also significantly higher yield than Agsh₂201/Agsh₂309, Agsh₂303/Agsh₂309 and Insee2 hybrids, but statistically not higher than the original hybrid, Agsh₂201/Agsh₂318, and yielded equally to the best commercial hybrid, Hybrix3. However, the commercial sweet corn hybrid, Hybrix3 was significantly higher husked ear yield than the best intra-set testcross hybrid but had lower recovery rate. In contrast, the other commercial sweet corn hybrid, Insee2 was significantly lower green and husked ear yield, percentage of marketable ears but higher recovery rate than the best intra-set testcross hybrid. The results revealed that the mean green and husked ear yield of intra-set testcross hybrids were highest where hybrids came from inbred lines selected under nil-competition environment in honeycomb design regardless of original parents. However, the other traits such as percentage of marketable ears, husked ear yield and recovery rate were not

statistically different between hybrids regardless of inbred line development methods across original parents. The results also showed very strong evidences for additive effect for the expression of heterosis since $L_{25}/L_{27}/L_{27}$ and $L_{25}/L_{27}/L_{25}$, which is essentially a backcross (F_1BC_1) hybrids yielded higher than its original parents.

However, one intra-set testcross hybrid ($L_{25}/L_{27}/L_{27}$) was significantly higher green ear yield ($15.07 \text{ tons ha}^{-1}$) than $Agsh_2201/Agsh_2309$ ($11.87 \text{ tons ha}^{-1}$) and $Agsh_2303/Agsh_2309$ ($11.47 \text{ tons ha}^{-1}$). Furthermore, another one hybrid ($L_{16}/L_{18}/L_{18}$) was also significantly higher husked ear yield ($7.77 \text{ tons ha}^{-1}$) than $Agsh_2303/Agsh_2309$ ($6.05 \text{ tons ha}^{-1}$) but statistically not higher than the original hybrid, $Agsh_2201/Agsh_2318$ ($7.37 \text{ tons ha}^{-1}$). This implied a strong additive effect for the expression of husked ear yield heterosis. Similar results in field corn were reported by Tokatlidis *et al.* (1998) of which recovered hybrids yielded higher than the original hybrid. The recovered inbred lines were also selected under nil-competition in honeycomb design.

Some agronomic and quality traits of 27 intra-set testcross hybrids and checks were presented in Table 8. The top yield intra-set testcross hybrids, $L_{25}/L_{27}/L_{27}$ and $L_{16}/L_{18}/L_{18}$ gave more or less similar performances as compared to the checks.

Table 6 Some important traits for commercial sweet corn hybrid of top intra-set (recovered) hybrids ($S_3 \times S_3$) of each set planted at Suwan Farm, Thailand in January, 2005 (dry season).

Rank	Pedigree	Green ear yield	Husked ear yield	% marketable ears	% husked ear yield	Recovery (%)	Ear length	Tip fill	Blank tip	Diameter	Kernel depth	Kernel row	Tenderness	Sweetness		
		Ton/ha		cm											1-5	%
1	L ₁ /L ₃	12.27 ^{c-g*}	8.08 ^{d-f}	85.90 ^{a-f}	66.15 ^{a-e}	34.51 ^{c-i}	17.8	16.4	1.4	3.88	0.75	14.5	2.0	13.90		
2	L ₅ /L ₆	11.40 ^{d-j}	7.70 ^{ef}	87.15 ^{a-f}	68.55 ^{a-d}	43.51 ^{a-d}	16.9	14.3	2.5	3.99	0.89	14.3	1.5	13.70		
3	L ₇ /L ₈	14.27 ^{bc}	9.63 ^{bc}	88.98 ^{a-e}	67.49 ^{a-d}	36.82 ^{a-i}	19.0	17.6	1.4	4.11	0.83	13.9	2.5	14.50		
4	L ₁₀ /L ₁₂	11.86 ^{c-h}	8.36 ^{d-f}	92.11 ^{a-d}	71.12 ^{a-b}	40.63 ^{a-f}	18.1	16.0	2.1	3.85	0.85	13.6	2.0	14.40		
5	L ₁₃ /L ₁₅	13.20 ^{c-e}	8.74 ^{c-e}	91.04 ^{a-d}	66.96 ^{a-d}	38.86 ^{a-h}	17.5	13.7	3.7	4.42	0.97	15.1	2.0	14.90		
6	L ₁₆ /L ₁₈	13.20 ^{c-e}	7.37 ^f	75.22 ^{c-h}	56.35 ^{b-e}	29.24 ^{e-i}	19.2	17.4	1.8	3.91	0.78	14.1	2.0	13.95		
7	L ₁₉ /L ₂₀	13.02 ^{c-f}	9.27 ^{b-d}	90.90 ^{a-d}	72.03 ^a	39.64 ^{a-g}	19.2	17.0	2.2	4.06	0.84	15.1	2.0	15.15		
8	L ₂₂ /L ₂₄	11.48 ^{d-i}	8.28 ^{d-f}	98.81 ^a	72.52 ^a	48.37 ^a	19.0	16.3	2.7	3.98	0.90	13.7	2.0	14.40		
9	L ₂₅ /L ₂₇	17.07 ^a	10.09 ^b	87.08 ^{a-f}	59.41 ^{a-e}	31.66 ^{d-i}	20.0	17.7	2.3	4.24	0.85	13.9	2.0	14.85		
Check1	Agsh ₂ -201/309	16.13 ^{ab}	11.39 ^a	95.00 ^{a-b}	70.11 ^{a-c}	39.89 ^{a-g}	20.3	18.0	2.3	4.27	0.92	15.1	2.0	14.10		
Check2	Agsh ₂ -303/309	16.20 ^{ab}	11.49 ^a	97.50 ^{a-b}	70.43 ^{a-b}	43.48 ^{a-d}	18.7	16.9	1.8	4.01	0.93	14.5	1.5	13.97		
Check3	Agsh ₂ -201/318	13.07 ^{c-e}	9.25 ^{b-d}	96.30 ^{a-b}	70.8 ^{a-b}	37.74 ^{a-i}	18.4	16.3	2.1	4.10	0.86	14.4	2.5	14.63		
Mean		12.15	8.44	86.48	66.00	37.45	18.1	15.9	2.2	4.00	0.85	14.2		14.36		
CV(%)		11.93	6.76	9.57	13.25	18.86	5.6	7.9	24.7	4.37	9.12	4.0		3.36		

* Means within a column followed by the same letter are not significantly different at $P \leq 0.05$ according to Duncan's multiple range test.

Table 7 Green ear and husked yield; percentage of husked ears, marketable yield and recovery of Intra-set testcross hybrids planted at Suwan Farm, Thailand in July 2005 (rainy season).

	Parent were extracted from Agsh2-201/309						Parent were extracted from Agsh2-303/309						Parent were extracted from Agsh2-201/318					
	Hybrid	Green ear yield (ton/ha)	Husked ear yield (ton/ha)	% marketable ears	% husked ear yield	Recovery (%)	Hybrid	Green ear yield (ton/ha)	Husked ear yield (ton/ha)	% marketable ears	% husked ear yield	Recovery (%)	Hybrid	Green ear yield (ton/ha)	Husked ear yield (ton/ha)	% marketable ears	% husked ear yield	Recovery (%)
HD	L ₁ /L ₃ /L ₁	10.20 ^{e-j*}	4.53 ^{k-m}	57.83 ^{e-f}	44.49 ^{f-g}	21.74 ^{f-g}	L ₅ /L ₆ /L ₄	9.40 ^{g-j}	4.17 ^{l-m}	61.26 ^{d-f}	44.30 ^{f-g}	26.84 ^{c-g}	L ₇ /L ₈ /L ₇	11.60 ^{c-h}	5.97 ^{d-k}	75.18 ^{a-d}	51.99 ^{b-g}	25.13 ^{d-g}
	L ₁ /L ₃ /L ₂	10.07 ^{e-j}	5.00 ^{h-m}	65.56 ^{b-f}	50.13 ^{c-g}	27.48 ^{b-g}	L ₅ /L ₆ /L ₅	9.93 ^{f-j}	4.67 ^{k-m}	60.44 ^{d-f}	47.02 ^{d-g}	25.35 ^{d-g}	L ₇ /L ₈ /L ₈	13.60 ^{a-d}	6.97 ^{b-f}	75.53 ^{a-d}	50.99 ^{b-g}	31.03 ^{b-e}
	L ₁ /L ₃ /L ₃	8.93 ^{h-j}	4.70 ^{k-m}	67.15 ^{a-f}	52.93 ^{a-g}	25.24 ^{d-g}	L ₅ /L ₆ /L ₆	11.13 ^{c-i}	5.77 ^{e-k}	67.14 ^{a-f}	52.23 ^{b-g}	31.05 ^{b-e}	L ₇ /L ₈ /L ₉	12.87 ^{a-e}	7.13 ^{b-e}	76.44 ^{a-d}	55.54 ^{a-d}	32.00 ^{b-e}
	Average	9.73	4.74	63.51	49.18	24.82	Average	10.15	4.87	62.95	47.85	27.75	Average	12.69	6.69	75.72	52.84	29.39
HC	L ₁₉ /L ₂₀ /L ₁₉	11.93 ^{c-g}	6.33 ^{b-j}	69.78 ^{a-f}	52.54 ^{a-g}	25.09 ^{d-g}	L ₂₂ /L ₂₄ /L ₂₂	11.47 ^{c-h}	6.53 ^{b-h}	67.53 ^{a-f}	50.01 ^{c-g}	33.44 ^{b-d}	L ₂₅ /L ₂₇ /L ₂₅	13.33 ^{a-d}	7.20 ^{b-e}	71.52 ^{a-f}	46.26 ^{e-g}	25.35 ^{d-g}
	L ₁₉ /L ₂₀ /L ₂₀	11.73 ^{c-h}	6.40 ^{b-i}	65.13 ^{b-f}	48.78 ^{c-g}	25.60 ^{d-g}	L ₂₂ /L ₂₄ /L ₂₃	11.87 ^{c-g}	5.87 ^{d-k}	57.97 ^{e-f}	46.31 ^{e-g}	30.30 ^{b-f}	L ₂₅ /L ₂₇ /L ₂₆	12.87 ^{a-e}	6.67 ^{b-g}	61.73 ^{c-f}	52.25 ^{b-g}	28.03 ^{b-g}
	L ₁₉ /L ₂₀ /L ₂₁	11.53 ^{c-h}	5.87 ^{d-k}	57.81 ^{e-f}	48.60 ^{c-g}	27.92 ^{b-g}	L ₂₂ /L ₂₄ /L ₂₄	10.93 ^{d-i}	6.00 ^{c-k}	64.23 ^{b-f}	54.02 ^{a-e}	33.38 ^{b-d}	L ₂₅ /L ₂₇ /L ₂₇	15.07 ^{a-b}	7.57 ^{b-c}	79.60 ^{a-b}	49.47 ^{c-g}	25.46 ^{d-g}
	Average	11.73	6.20	64.24	49.97	26.20	Average	11.42	6.13	63.24	50.11	32.37	Average	13.76	7.15	70.95	49.33	26.28
Alter	L ₁₀ /L ₁₂ /L ₁₀	10.87 ^{d-j}	4.87 ^{i-m}	61.67 ^{c-f}	45.55 ^{e-g}	23.79 ^{e-g}	L ₁₃ /L ₁₅ /L ₁₃	12.13 ^{c-g}	7.10 ^{b-e}	75.16 ^{a-d}	56.10 ^{a-d}	35.21 ^{b-c}	L ₁₆ /L ₁₈ /L ₁₆	12.40 ^{b-f}	6.07 ^{c-k}	65.68 ^{b-f}	49.44 ^{c-g}	26.27 ^{d-g}
	L ₁₀ /L ₁₂ /L ₁₁	8.47 ^{i-j}	3.67 ^m	55.51 ^f	43.82 ^g	21.23 ^g	L ₁₃ /L ₁₅ /L ₁₄	10.13 ^{e-j}	4.80 ^{j-m}	68.68 ^{a-f}	45.71 ^{e-g}	25.61 ^{d-g}	L ₁₆ /L ₁₈ /L ₁₇	11.07 ^{c-i}	5.43 ^{f-l}	75.94 ^{a-d}	49.13 ^{c-g}	23.23 ^{e-g}
	L ₁₀ /L ₁₂ /L ₁₂	8.20 ^j	4.20 ^{l-m}	61.12 ^{d-f}	51.32 ^{b-g}	29.30 ^{b-g}	L ₁₃ /L ₁₅ /L ₁₅	11.47 ^{c-h}	6.47 ^{b-h}	72.78 ^{a-e}	49.85 ^{c-g}	32.04 ^{b-e}	L ₁₆ /L ₁₈ /L ₁₈	13.80 ^{a-c}	7.77 ^b	73.35 ^{a-e}	56.44 ^{a-c}	30.52 ^{b-f}
	Average	9.18	4.25	59.43	46.90	24.77	Average	11.24	6.12	72.21	50.55	30.95	Average	12.42	6.42	71.66	51.67	26.67
Origin hybrids	Agsh ₂ -201/309	11.87 ^{c-g}	7.25 ^{b-e}	77.72 ^{a-c}	61.15 ^a	43.19 ^a	Agsh ₂ -303/309	11.47 ^{c-h}	6.05 ^{c-k}	69.20 ^{a-f}	53.50 ^{a-f}	26.74 ^{c-g}	Agsh ₂ -201/318	12.90 ^{a-e}	7.37 ^{b-d}	76.01 ^{a-d}	56.83 ^{a-c}	32.84 ^{b-d}
Check	Hybrid ₃	15.47 ^a	9.30 ^a	81.89 ^a	59.90 ^{a-b}	23.35 ^{c-g}	Insee ₂	11.80 ^{c-g}	5.37 ^{g-l}	65.84 ^{a-f}	45.58 ^{e-g}	35.79 ^b						

* Means within a column followed by the same letter are not significantly different at $P \leq 0.05$ according to Duncan's multiple range test.

Table 8 Some agronomic and quality traits for commercial sweet corn of Intra-set testcross hybrids, planted at Suwan Farm, Thailand in July, 2005 (rainy season).

Rank Order ^{1/}	Hybrid	Ear length	Tip fill	Blank tip	Diameter	Kernel depth	Kernel row	Tenderness	Sweetness
		cm						1-5 ^{2/}	%
1	L ₁ /L ₃ //L ₁	16.73	15.30	1.43	3.72	0.66	13.23	2.0	13.58
2	L ₁ /L ₃ //L ₂	17.41	15.80	1.61	3.86	0.68	14.30	2.0	13.30
3	L ₁ /L ₃ //L ₃	17.54	16.58	0.96	3.71	0.64	13.60	1.5	12.50
4	L ₅ /L ₆ //L ₄	16.65	14.79	1.87	3.93	0.73	14.30	1.5	12.85
5	L ₅ /L ₆ //L ₅	16.57	13.74	2.83	3.84	0.74	14.00	2.0	13.30
6	L ₅ /L ₆ //L ₆	17.20	14.93	2.28	4.31	0.71	14.90	1.5	13.80
7	L ₇ /L ₈ //L ₇	17.80	17.06	0.74	3.95	0.71	13.60	2.5	13.55
8	L ₇ /L ₈ //L ₈	17.41	16.06	1.35	3.94	0.79	13.80	2.5	14.30
9	L ₇ /L ₈ //L ₉	19.03	17.39	1.64	3.96	0.79	13.15	2.5	14.45
10	L ₁₀ /L ₁₂ //L ₁₀	17.73	15.80	1.93	3.69	0.71	12.93	2.0	14.10
11	L ₁₀ /L ₁₂ //L ₁₁	16.30	14.60	1.70	3.73	0.68	13.08	1.5	14.40
12	L ₁₀ /L ₁₂ //L ₁₂	17.83	15.81	2.02	3.81	0.76	13.20	2.0	12.60
13	L ₁₃ /L ₁₅ //L ₁₃	16.50	14.25	2.25	3.97	0.79	13.70	1.5	14.35
14	L ₁₃ /L ₁₅ //L ₁₄	18.47	16.29	2.18	4.20	0.90	14.00	1.0	14.30
15	L ₁₃ /L ₁₅ //L ₁₅	18.28	15.74	2.54	4.21	0.84	14.70	1.5	15.40
16	L ₁₆ /L ₁₈ //L ₁₆	19.76	17.84	1.92	4.06	0.78	13.70	2.5	13.85
17	L ₁₆ /L ₁₈ //L ₁₇	17.45	16.83	0.63	3.46	0.65	13.00	2.5	13.65
18	L ₁₆ /L ₁₈ //L ₁₈	18.68	17.68	1.01	4.02	0.86	13.60	2.5	14.70
19	L ₁₉ /L ₂₀ //L ₁₉	18.51	17.35	1.16	3.71	0.66	13.80	1.5	14.60
20	L ₁₉ /L ₂₀ //L ₂₀	17.85	15.51	2.35	3.66	0.63	14.30	2.0	14.75
21	L ₁₉ /L ₂₀ //L ₂₁	18.94	16.93	2.02	3.93	0.66	15.23	2.0	15.45
22	L ₂₂ /L ₂₄ //L ₂₂	18.74	16.09	2.66	3.58	0.66	13.60	1.5	13.30
23	L ₂₂ /L ₂₄ //L ₂₃	17.48	14.90	2.58	4.03	0.78	13.90	1.0	14.60
24	L ₂₂ /L ₂₄ //L ₂₄	17.23	15.41	1.82	3.72	0.67	13.60	1.0	14.20
25	L ₂₅ /L ₂₇ //L ₂₅	18.85	17.51	1.35	3.97	0.79	13.20	2.5	13.55
26	L ₂₅ /L ₂₇ //L ₂₆	16.50	15.48	1.03	3.87	0.61	12.90	2.5	14.10
27	L ₂₅ /L ₂₇ //L ₂₇	18.45	17.85	0.60	4.00	0.74	13.20	2.5	14.40
Check 1	Agsh ₂ -201/309	19.71	17.78	1.93	4.19	0.74	14.88	2.0	14.20
Check 2	Agsh ₂ -303/309	18.43	16.23	2.21	3.88	0.72	14.10	1.5	13.50
Check 3	Agsh ₂ -201/318	18.01	16.80	1.21	4.18	0.83	13.40	2.5	14.63
Check 4	Hybrid ₃	20.50	19.50	1.00	4.85	0.86	17.20	1.0	14.55
Check 5	Insee ₂	18.39	16.70	1.69	4.18	0.71	14.15	1.5	15.00
Mean		17.96	16.26	1.70	3.94	0.73	13.88		14.05
%CV		4.69	5.48	45.26	5.50	15.34	5.55		5.90

^{1/} 1-9: Hybrids were derived from HD; 10-18: hybrids were derived from alternated and 19-27 which were derived from HC.

^{2/} 1: very thin pericarp; 5: very thick pericarp; 2.5: acceptable level

5. Double modified single cross or sister line cross yield trial.

Because all S₄ lines were weakened and susceptible to leaf diseases. In order to boost up parent yield, top recovered hybrids, each was selected from each set will be used as parents to form sister line crosses. However, for simplicity, the recovered hybrids and sister line crosses will be referred to as lines and double crosses, respectively.

Green and husked ear yield with some important traits for commercial sweet corn of double cross hybrids derived from lines selected by the same selection method were presented in Table 9. Mean of green ear yield of hybrids generated from crosses between lines extracted under alternate environments were higher than crosses between lines extracted under high plant density or nil-competition environments. Crosses between lines developed under alternate environments were also showed higher husked ear yield than crosses between lines extracted by the other two methods, and as so for percentage of marketable ear, husked ear yield and recovery rate.

Out of 36 double cross hybrids, 1 hybrid showed similar green ear yield to the best commercial check hybrid, Hybrix3, but somewhat higher yield than Insee2 even though it was statistically not significant (Table 10) and 11 hybrids gave higher green ear yield although statistically not different with the second best commercial check hybrid, Insee2, one of them were significantly higher than the best original hybrid. On the other hand, there were 16 double cross hybrids which gave equally husked ear yield to the best check hybrid, Hybrix3. The best two double cross hybrids for both green and husked ear yield were L₁₃/L₁₅//L₁₆/L₁₈ and L₁₀/L₁₂//L₁₆/L₁₈. L₁₆/L₁₈ also had highest combining ability among the 9 selected lines (Table 9 and Table 10). The L₂₂/L₂₄ derived from crossing of 2 high yielding lines (Table 1) but it was only 5th in the rank of combining ability among 9 selected lines. Considering parent' yield in Table 6: L₁/L₃, L₇/L₈, L₁₃/L₁₅, L₁₆/L₁₈, L₁₄/L₂₀, L₂₅/L₂₇ and L₁₀/L₁₂ were high yield lines; L₅/L₆ and L₂₂/L₂₄ were low yield lines. The high yield line L₁/L₃ failed to produce the top-10 double cross hybrids. Five of the top-10 double cross hybrids were

from H x H and the remaining 5 double cross hybrids were came from H x L. However, L₁₆/L₁₈, L₁₃/L₁₅ and L₂₅/L₂₇ which were ranked 1st, 2nd and 3rd for general combining ability for both green and husked ear yield were involved in 9 out of top-10 double cross hybrids. The top-3 double cross hybrids were came from H x H while L₂₂/L₂₄ which were ranked 5th for general combining ability and low yield involved in 4 out of top-10 double cross hybrids. L₁₃, L₁₅, L₁₆ and L₁₈ were selected under alternate environments while L₂₅ and L₂₇ were selected under isolation environment.

Marketable ear percentage of the top double cross hybrid was 93.65 and statistically not different from 80.90 and 79.85 percent of the commercial sweet corn hybrids, Insee2 and Hybrix3. However, there were 5 double cross hybrids gave significantly higher percentage of husked ear yield than the best commercial sweet corn check, Hybrix3. Moreover, two commercial hybrids, Hybrix3 and Insee2 also had significantly lower recovery percentage than the top-9 double cross hybrids. These results might be due to the lower of husked ear yield and recovery percentage of Hybrix3 and Insee2 than the original hybrids, Agsh₂201/Agsh₂309, Agsh₂303/Agsh₂309 and Agsh₂201/Agsh₂318 (Appendix Table 9 to Appendix Table 13).

Moreover, most of agronomic and quality traits for commercial sweet corn hybrid of double cross hybrids were similar to the commercial checks and the original hybrids (Table 11). This is because of all breeding germplasm used in this study are leading hybrids which have been selected for high quality. The results demonstrated that additive effect is more important than the non additive effect for the contribution to heterosis in maize hybrids. However, high yielding inbred alone does not ensure for high performance in hybrid combination because diversity of desirable genes at different loci of parent lines is needed to maximize heterosis effect in hybrid combination because cumulative (additive) effect occurs in both intra- and inter- loci (Fasoula and Fasoula, 2002, Falconer and Macky, 1996). Therefore, effective breeding scheme should be the one that effectively identified high yield inbred with high combining ability.

Table 9 Some important traits for commercial sweet corn hybrid of sister line crosses generated from crosses between HD x HD, HC x HC and Alternate x Alternate inbred lines, planted at Suwan Farm, Thailand in July, 2005 (rainy season).

Type ^{1/}	Pedigree	Green ear yield	Husked ear yield	% marketable ears	% husked ear yield	Recovery (%)	Ear length	Tip fill	Blank tip	Diameter	Kernel depth	Kernel row	Tenderness	Sweetness
		Ton/ha						cm				1-5	%	
HD	L ₁ /L ₃ //L ₅ /L ₆	10.93 ^{h-ik}	7.00 ^{g-l}	83.96 ^{a-c}	63.85 ^{b-f}	41.56 ^{a-g}	16.44	15.02	1.42	3.92	0.78	14.00	2.0	13.00
x	L ₁ /L ₃ //L ₇ /L ₈	10.33 ^{j-l}	6.57 ^{h-l}	85.23 ^{a-d}	63.70 ^{b-f}	36.55 ^{c-j}	17.87	17.27	0.60	3.79	0.95	13.60	2.0	14.80
HD	L ₅ /L ₆ //L ₇ /L ₈	12.47 ^{c-l}	8.20 ^{b-j}	78.77 ^{b-g}	65.73 ^{a-e}	37.70 ^{b-j}	18.35	17.15	1.20	4.13	0.96	13.80	2.0	12.95
	Average	11.24	7.26	82.65	64.43	38.60	17.55	16.48	1.07	3.95	0.90	13.80	2.00	13.58
Al	L ₁₀ /L ₁₂ //L ₁₃ /L ₁₅	13.07 ^{c-k}	8.07 ^{c-j}	79.89 ^{a-g}	62.15 ^{c-f}	39.43 ^{a-i}	17.63	15.52	2.11	3.30	0.73	14.00	1.5	14.35
x	L ₁₀ /L ₁₂ //L ₁₆ /L ₁₈	15.00 ^{a-c}	10.43 ^a	88.65 ^{a-d}	69.55 ^{a-c}	42.97 ^{a-d}	19.21	18.74	0.47	3.64	0.98	13.60	2.0	13.95
Al	L ₁₃ /L ₁₅ //L ₁₆ /L ₁₈	16.27 ^{a-b}	10.30 ^{a-b}	88.83 ^{a-d}	63.66 ^{b-f}	41.32 ^{a-g}	18.15	17.29	0.86	4.06	0.81	13.20	2.0	13.55
	Average	14.78	9.60	85.79	65.12	41.24	18.33	17.18	1.15	3.67	0.84	13.60	1.83	13.95
HC	L ₁₉ /L ₂₀ //L ₂₂ /L ₂₄	10.33 ^{j-l}	6.07 ^{j-l}	69.20 ^{f-g}	58.48 ^{e-g}	37.55 ^{b-j}	18.16	16.32	1.85	3.79	0.92	13.50	2.0	13.80
x	L ₁₉ /L ₂₀ //L ₂₅ /L ₂₇	11.80 ^{d-l}	7.67 ^{d-l}	83.11 ^{a-e}	65.04 ^{a-f}	39.35 ^{a-i}	18.52	17.99	0.54	4.18	0.93	13.70	2.0	13.75
HC	L ₂₂ /L ₂₄ //L ₂₅ /L ₂₇	14.33 ^{a-e}	9.70 ^{a-e}	87.95 ^{a-d}	67.94 ^{a-d}	42.36 ^{a-e}	19.52	18.56	0.96	4.43	0.96	14.40	1.0	14.25
	Average	12.15	7.81	80.09	63.82	39.75	18.73	17.62	1.12	4.13	0.94	13.87	1.67	13.93
Check1	Agsh ₂ 201/Agsh ₂ 309	12.27 ^{c-l}	8.68 ^{a-h}	86.01 ^{a-d}	70.63 ^{a-b}	43.45 ^{a-d}	18.78	17.22	1.56	3.98	0.88	14.75	1.5	13.45
Check2	Agsh ₂ 303/Agsh ₂ 309	12.83 ^{c-k}	8.32 ^{a-i}	77.10 ^{c-g}	64.93 ^{a-f}	41.51 ^{a-g}	17.86	16.00	1.86	3.77	0.72	14.59	1.5	13.78
Check3	Agsh ₂ 201/Agsh ₂ 318	12.00 ^{c-l}	8.12 ^{c-j}	86.14 ^{a-d}	67.55 ^{a-d}	41.17 ^{a-g}	17.41	16.62	0.79	4.09	0.95	13.35	2.0	13.88
Check4	Insee2	13.47 ^{b-h}	7.80 ^{d-k}	80.90 ^{a-f}	57.82 ^{f-g}	31.50 ^j	18.59	17.65	0.95	3.94	1.05	13.50	1.5	15.00
Check5	Hybrid3	16.87 ^a	10.43 ^a	79.85 ^{a-g}	61.78 ^{d-g}	34.83 ^{f-j}	19.44	18.04	1.40	4.92	1.08	17.30	1.0	13.65
	Mean	12.66	8.24	83.32	64.90	39.20	18.05	16.98	1.07	3.89	0.88	13.97		13.73
	CV(%)	13.60	15.10	9.55	6.73	10.74	4.18	5.04	62.49	10.35	9.67	4.18		8.08

^{1/} HD = high density selection, Al = alternate selection and HC = honeycomb selection.

* Means within a column followed by the same letter are not significantly different at P≤0.05 according to Duncan's multiple range test.

Table 10 Green ear, husked ear yields and some important traits for sweet corn hybrid of top ten green ear yield double modified single cross hybrids planted at Suwan Farm, Thailand in July, 2005 (rainy season)

Rank order	Pedigree	Green yield	Husked ear yield	% marketable ears	% husked ear yield	Recovery (%)	Parent lines	Green ear yield (ton/ha)	General Combining ability
		Ton/ha							
1	L ₁₃ /L ₁₅ //L ₁₆ /L ₁₈	16.27 ^{a-b*}	10.30 ^{a-b}	88.83 ^{a-d}	63.66 ^{b-f}	41.32 ^{a-g}	L ₁ /L ₃	12.27 ^{c-g}	- 1.41
2	L ₁₀ /L ₁₂ //L ₁₆ /L ₁₈	15.00 ^{a-c}	10.43 ^a	88.65 ^{a-d}	69.55 ^{a-c}	42.97 ^{a-d}	L ₅ /L ₆	11.40 ^{d-j}	- 0.46
3	L ₁₃ /L ₁₅ //L ₂₅ /L ₂₇	14.53 ^{a-d}	9.23 ^{a-f}	87.79 ^{a-d}	63.74 ^{b-f}	32.94 ^{i-j}	L ₇ /L ₈	14.27 ^{bc}	0.08
4	L ₂₂ /L ₂₄ //L ₂₅ /L ₂₇	14.33 ^{a-e}	9.70 ^{a-e}	87.95 ^{a-d}	67.94 ^{a-d}	42.36 ^{a-c}	L ₁₀ /L ₁₂	11.86 ^{c-h}	- 0.48
5	L ₇ /L ₈ //L ₂₂ /L ₂₄	14.27 ^{a-e}	9.57 ^{a-e}	88.58 ^{a-d}	67.03 ^{a-d}	44.42 ^{a-b}	L ₁₃ /L ₁₅	13.20 ^{c-e}	1.03
6	L ₁₆ /L ₁₈ //L ₂₂ /L ₂₄	14.27 ^{a-e}	10.27 ^{a-b}	93.65 ^a	71.74 ^a	45.67 ^a	L ₁₆ /L ₁₈	13.20 ^{c-e}	1.26
7	L ₇ /L ₈ //L ₁₃ /L ₁₅	14.13 ^{a-f}	9.70 ^{a-e}	90.35 ^{a-c}	68.27 ^{a-d}	43.21 ^{a-d}	L ₁₉ /L ₂₀	13.02 ^{c-f}	- 0.75
8	L ₅ /L ₆ //L ₁₆ /L ₁₈	14.00 ^{b-g}	9.97 ^{a-c}	90.43 ^{a-c}	71.09 ^{a-b}	43.75 ^{a-c}	L ₂₂ /L ₂₄	11.48 ^{d-i}	- 0.01
9	L ₁₃ /L ₁₅ //L ₂₂ /L ₂₄	13.87 ^{b-h}	9.07 ^{a-g}	85.69 ^{a-d}	65.35 ^{a-f}	42.72 ^{a-e}	L ₂₅ /L ₂₇	17.07 ^a	0.74
10	L ₁₆ /L ₁₈ //L ₁₉ /L ₂₀	13.87 ^{b-h}	9.77 ^{a-d}	93.62 ^a	70.64 ^{a-b}	40.26 ^{a-i}			
Check1	Agsh ₂ 201/Agsh ₂ 309	12.27 ^{c-l}	8.68 ^{a-h}	86.01 ^{a-d}	70.63 ^{a-b}	43.45 ^{a-d}			
Check2	Agsh ₂ 303/Agsh ₂ 309	12.83 ^{c-k}	8.32 ^{a-i}	77.10 ^{c-g}	64.93 ^{a-f}	41.51 ^{a-g}			
Check3	Agsh ₂ 201/Agsh ₂ 318	12.00 ^{c-l}	8.12 ^{c-j}	86.14 ^{a-d}	67.55 ^{a-d}	41.17 ^{a-g}			
Check4	Insee2	13.47 ^{b-h}	7.80 ^{d-k}	80.90 ^{a-f}	57.82 ^{f-g}	31.50 ^j			
Check5	Hybrid3	16.87 ^a	10.43 ^a	79.85 ^{a-g}	61.78 ^{d-g}	34.83 ^{f-j}			
	Mean	12.66	8.24	83.32	64.90	39.20			
	CV(%)	13.60	15.10	9.55	6.73	10.74			

* Means within a column followed by the same letter are not significantly different at P≤0.05 according to Duncan's multiple range test.

Table 11 Some agronomic and quality traits for commercial sweet corn of double cross hybrids, planted at Suwan Farm, Thailand in July, 2005 (rainy season).

Rank order	Hybrid	Ear length	Tip fill	Blank tip	Diameter	Kernel depth	Kernel row	Tenderness	Sweetness
								1-5	%
				cm					
1	L ₁ /L ₃ //L ₅ /L ₆	16.44	15.02	1.42	3.92	0.78	14.00	2.0	13.00
2	L ₁ /L ₃ //L ₇ /L ₈	17.87	17.27	0.60	3.79	0.95	13.60	2.0	14.80
3	L ₁ /L ₃ //L ₁₀ /L ₁₂	17.93	16.71	1.22	3.84	0.83	14.20	1.0	14.65
4	L ₁ /L ₃ //L ₁₃ /L ₁₅	17.60	16.53	1.07	4.10	0.98	14.30	2.0	12.95
5	L ₁ /L ₃ //L ₁₆ /L ₁₈	18.12	17.58	0.54	3.82	0.78	13.70	2.0	12.80
6	L ₁ /L ₃ //L ₁₉ /L ₂₀	16.97	15.88	1.09	3.66	0.73	14.40	1.5	14.05
7	L ₁ /L ₃ //L ₂₂ /L ₂₄	17.53	16.62	0.90	3.87	0.92	13.95	1.5	13.40
8	L ₁ /L ₃ //L ₂₅ /L ₂₇	18.59	17.87	0.73	3.83	0.72	14.20	2.0	12.75
9	L ₅ /L ₆ //L ₇ /L ₈	18.35	17.15	1.20	4.13	0.96	13.80	2.0	12.95
10	L ₅ /L ₆ //L ₁₀ /L ₁₂	17.24	15.29	1.95	3.52	0.83	13.40	1.5	13.65
11	L ₅ /L ₆ //L ₁₃ /L ₁₅	15.98	15.43	0.56	4.10	1.13	13.90	1.5	13.55
12	L ₅ /L ₆ //L ₁₆ /L ₁₈	18.42	17.83	0.59	4.10	1.05	13.80	2.0	12.40
13	L ₅ /L ₆ //L ₁₉ /L ₂₀	17.39	15.74	1.65	3.96	1.04	14.80	1.0	14.05
14	L ₅ /L ₆ //L ₂₂ /L ₂₄	16.94	15.72	1.22	3.84	0.88	14.10	1.5	12.75
15	L ₅ /L ₆ //L ₂₅ /L ₂₇	18.47	17.26	1.21	4.29	0.79	14.70	2.0	13.05
16	L ₇ /L ₈ //L ₁₀ /L ₁₂	18.01	17.30	0.71	3.77	0.72	13.90	2.0	14.50
17	L ₇ /L ₈ //L ₁₃ /L ₁₅	18.54	17.05	1.50	4.04	1.07	13.60	2.0	14.30
18	L ₇ /L ₈ //L ₁₆ /L ₁₈	17.84	17.30	0.54	3.68	0.81	12.40	2.5	13.95
19	L ₇ /L ₈ //L ₁₉ /L ₂₀	17.87	17.20	0.68	3.49	0.69	14.50	1.5	13.55
20	L ₇ /L ₈ //L ₂₂ /L ₂₄	18.68	17.94	0.73	3.97	0.97	14.50	1.5	14.20
21	L ₇ /L ₈ //L ₂₅ /L ₂₇	17.76	16.84	0.92	3.49	0.88	13.40	2.5	12.95
22	L ₁₀ /L ₁₂ //L ₁₃ /L ₁₅	17.63	15.52	2.11	3.30	0.73	14.00	1.5	14.35
23	L ₁₀ /L ₁₂ //L ₁₆ /L ₁₈	19.21	18.74	0.47	3.64	0.98	13.60	2.0	13.95
24	L ₁₀ /L ₁₂ //L ₁₉ /L ₂₀	17.65	16.08	1.57	3.40	0.83	13.60	1.0	14.75
25	L ₁₀ /L ₁₂ //L ₂₂ /L ₂₄	18.57	16.73	1.84	3.87	0.96	14.10	1.0	13.75
26	L ₁₀ /L ₁₂ //L ₂₅ /L ₂₇	18.57	18.14	0.43	3.75	0.78	13.90	2.0	14.85
27	L ₁₃ /L ₁₅ //L ₁₆ /L ₁₈	18.15	17.29	0.86	4.06	0.81	13.20	2.0	13.55
28	L ₁₃ /L ₁₅ //L ₁₉ /L ₂₀	17.87	16.56	1.31	4.04	0.83	14.00	1.5	14.10
29	L ₁₃ /L ₁₅ //L ₂₂ /L ₂₄	17.33	15.98	1.35	3.73	0.94	13.70	1.5	13.80
30	L ₁₃ /L ₁₅ //L ₂₅ /L ₂₇	18.34	17.25	1.09	4.26	0.99	14.00	2.0	13.00
31	L ₁₆ /L ₁₈ //L ₁₉ /L ₂₀	19.36	18.58	0.78	3.62	0.69	13.70	1.5	14.45
32	L ₁₆ /L ₁₈ //L ₂₂ /L ₂₄	18.67	18.30	0.37	3.87	0.89	13.90	2.0	13.35
33	L ₁₆ /L ₁₈ //L ₂₅ /L ₂₇	18.08	17.32	0.76	3.94	0.95	12.90	2.5	13.55
34	L ₁₉ /L ₂₀ //L ₂₂ /L ₂₄	18.16	16.32	1.85	3.79	0.92	13.50	2.0	13.80
35	L ₁₉ /L ₂₀ //L ₂₅ /L ₂₇	18.52	17.99	0.54	4.18	0.93	13.70	2.0	13.75
36	L ₂₂ /L ₂₄ //L ₂₅ /L ₂₇	19.52	18.56	0.96	4.43	0.96	14.40	1.0	14.25
Check 1	Agsh ₂ -201/309	18.78	17.22	1.56	3.98	0.88	14.75	1.5	13.45
Check 2	Agsh ₂ -303/309	17.86	16.00	1.86	3.77	0.72	14.59	1.5	13.78
Check 3	Agsh ₂ -201/318	17.41	16.62	0.79	4.09	0.95	13.35	2.0	13.88
Check4	Hybrid 3	19.44	18.04	1.40	4.92	1.08	17.30	1.0	13.65
Check5	Insee 2	18.59	17.65	0.95	3.94	1.05	13.50	1.5	15.00
Mean		18.05	16.98	1.07	3.89	0.88	13.97		13.73
%CV		4.18	5.04	62.49	10.35	9.67	4.18		8.08

^{1/} 1-9: Hybrids were derived from HD; 10-18: hybrids were derived from alternated and 19-27 which were derived from HC.

^{2/} 1: very thin pericarp; 5: very thick pericarp; 2.5: acceptable level

CONCLUSION

The results suggested that honeycomb selection in the absence of competition with controlled selfing and testing for combining ability in early generation were effective for improving potential yield of both inbred lines and hybrids. Selection in maize should be based on productivity of inbred through selfing and selection in order to exploit the favorable additive alleles and eliminate the deleterious gene effects. In other words, selfing and selection for inbred line performance per se in combination with testing for combining ability are necessary to identify good hybrid which is effectively utilized additive effect of both intra and inter loci as well as other kinds of non-additive function. Lines which were selected under alternate plant spacing also proved to be useful for inter-set hybrids. Selection under high plant density was apparently less efficient than the other two methods.

Recovered lines and hybrids have been proved to be very useful method for the improvement of original inbred parents to facilitate hybrid seed production. Even though there are several factors which may affect the efficiency of the method. Original inbred parents should be used as testers to identify good combinations of recovered hybrids. However, non-related testers are still necessary to identify new and better hybrids. For present study, intra-set three-way cross (recovered three way hybrid) and double modified single cross (sister line cross) performed better than intra-set single cross (recovered hybrid) due to weakening and more susceptible to disease of recovered inbred lines.

LITERATURE CITED

- Allard, R. W. 1960. **Principles of Plant Breeding**. John Wiley and son, New York.
- Bauman, L. F. 1981. Review of methods used by corn breeders to develop superior corn inbreds. **Proceedings Annual Corn and Sorghum Industry Research Conference**, 36:199-208.
- Brown, W. L. 1953. Source of germplasm for hybrid corn. **Proc. Annu. Hybrid corn industry, Res. Conf.** 8: 11-16.
- Castleberry, R. M., C. W. Crum and C. F. Krull. 1984. Genetic yield improvement of U.S. maize cultivars under varying fertility and climatic environments. **Crop Sci.** 24:33-36.
- Castellanos, J.S., A.R. Hallauer and H.S. Cordova, 1998. Relative performance of testers to identify elite lines of corn (*Zea mays* L.). **Maydica** 43: 217-226.
- Dhillon, B. S and A. S. Khehra. 1989. Modified S₁ recurrent selection in maize improvement. **Crop Sci.** 29:226-228.
- Donald, C. M. and J. Hamblin. 1976. The biological yield and harvest index of yield as agronomic and plant breeding criteria. **Adv. Agron.** 28:361-405
- Duvick, D. N. 1992. Genetic contributions to advances in yield of U.S. maize. **Maydica** 37:69-79.
- Duvick, D. N. 1997. What is yield? *In* G. O. Edmeades, B. Banzinger, H. R. Mickelson and C. B. Pena-Valdivia, (eds). Developing Drought and Low N-Tolerance Maize. Proceeding of a Symposium. March 25-29. 1996. CIMMYT, El Batan, Mexico. **CIMMYT, Mexico.**

- Duvick, D.N. 1999. Heterosis: Feeding people and protecting natural resources, pp. 19-29. *In* J.G. Coors and S. Pandey, eds. **Genetic and Exploitation of Heterosis Crops**. ASA, CSSA, and SSSA, Madison.
- Empig, L. T., C. O. Gardner and W. A. Compton. 1972. **Theoretical gains for different population improvement procedures**. Nebr., Agric. Exp. Stn., Bull. M26(rev.), 1-22.
- Falconer, D. S. 1981. **Introduction to quantitative genetics**. Longman, London.
- Falconer, D. S. 1989. **Introduction to Quantitative Genetics**. 3rd ed. Longman Group Ltd., New York.
- Falconer, D. S and T. F. C. Mackay. 1996. **Introduction to quantitative genetics**. 4th ed. Longman, Essex, England.
- Fasoula, A. C. 1973. **A new approach to breeding superior yielding varieties**. Pub. 3. Dept. Genetic Plant Breeding, Aristotelian Univ. P.O.Box 1555, GR-54006 Thessaloniki 17 Greece.
- Fasoulas, A. C. 1974. **Evolution of genetic systems**. Pub. 4. Dept. Genetic Plant Breeding, Aristotelian Univ. P.O.Box 1555, GR-54006 Thessaloniki 17 Greece.
- Fasoula, D. A. 1990. Correlation between auto-, allo- and nil-competition and their implications in plant breeding. **Euphytica** 50: 57-62.
- Fasoula, A. C. 1993. **Principles of crop breeding**. P.O.Box 1555, GR-54006 Thessaloniki 17 Greece.
- Fasoulas, A. C and V. A. Fasoula. 1995. Honeycomb selection designs. **Plant Breeding Review** 13: 87-139.

- Fasoula, D.A and V.A. Fasoula. 1997. Competitive ability and plant breeding. **Plant Breeding Review** 14:89-138.
- Fasoulas, A. C. 1997. Overcoming inbred line stagnation for productivity and stability in maize breeding. pp. 115-124. *In* A. S. Tsafaris (ed.). **Proc. XVII Conf.** In Genetics, Biotechnology, and Breeding of Maize and Sorghum. Royal Soc. Chem. Cambridge.
- Fasoula, V. A and D. A. Fasoula. 1999. Honeycomb Breeding: Principles and Applications. **Plant Breeding Review** 18: 177-250.
- Fasoula, D. A and V. A. Fasoula. 2002. Principle underlying genetic improvement for high and stable crop yield potential. **Field Crop Research** 75: 191-209.
- Fery, R. L. and J. Janick. 1970. Response of the tomato to population pressure. **J. Am. Soc. Hort. Sci.** 95: 614-624.
- Gallais, A. 1997. Combined testcross and S₁ selection for the improvement of testcross and inbred performances. **Crop Sci.** 37: 1126-1133.
- Hallauer, A. R and J. B. Miranda. 1981. **Quantitative Genetics in Maize Breeding.** Iowa State University Press. Ames.
- Hallauer, A. R. 1985. Compendium of recurrent selection methods and their application. Critical Review in **Plant Sci.** 3: 1-33.
- Hallauer, A. R and J. B. Miranda. 1988. **Quantitative Genetics in Maize Breeding.** 2nded. Iowa State University Press, Ames.
- Hallauer, A. R. 1989. Methods used in developing maize inbreds. **Maydica** 35: 1-16.

- Hamblin, J., R. Knight and M. J. Atkinson. 1978. The influence of systematic micro environmental variation on individual plant yield within selection plots. **Euphytica** 27: 497-503.
- Hansen, L. A., J. R. Baggett and K. E. Rowe. 1977. Quantitative genetic analysis of ten characteristics in sweet corn (*Zea mays* L.) **J. Am. Soc. Hort. Sci.** 102: 158-162.
- Harrington, J. B. 1952. **Cereal breeding procedures**. FAO Rome. pp. 28.
- Janick, J. 1999. Exploitation of heterosis: Uniformity and stability. pp 319-333. *In* **The genetics and exploitation of heterosis in crop**. ASA-CSSA-SSSA. Madison.
- Jensen, N. F. 1988. **Plant breeding methodology**. John Wiley and Son, New York.
- Jones, D. F and W. R. Singleton. 1934. Crossed sweet corn. **Connecticut Agr. Exp. Sta. Bull.** 361:491-536.
- Karl, K and D. W. Davis. 1986. Sweet corn breeding. pp 475-519. M. J. Basset (ed.), **Breeding vegetable crops**. AVI, Westport.
- Kyriakou, D. T. and A. C. Fasoulas. 1985. Effects of competition and selection pressure on yield response in winter rye (*Secale cereale* L.). **Euphytica** 34: 883-895.
- Labate, J. A., K. R. Lamkey, M. Lee and W. L. Woodman. 1999. Temporal changes in allele frequencies in two reciprocally selected maize populations. **Theor. Appl. Genet.** 99: 1166-1178.

- Lamkey, K. R and A. R. Hallauer. 1986. Performance of High x High, High x Low, and Low x Low cross of lines from the BSSS maize synthetic. **Crop Sci.** 26: 144-188.
- Lonnquist, J. H. 1953. Heterosis and yield of grain in maize. **Agron. J.** 45: 539-542.
- Lonnquist, J. H and D. P. McGill. 1956. Performance of corn synthetics in advanced generations of synthesis and after two cycles of recurrent selection. **Agron. J.** 48: 249-253.
- Marqueze-Sanchez, F. 1990. Backcross theory for maize. I. Homocigosis and heterosis. **Maydica** 35: 17-22.
- Marqueze-Sanchez, F. 1992. Backcross theory for maize. II. Additive genetic variance and response to selection. **Maydica** 37: 225-229.
- Marqueze-Sanchez, F. 1993. Backcross theory for maize. III. Crosses between contemporary backcrosses. **Maydica** 38: 61-66.
- Marquez-Sanchez, F. 1995. Backcross theory for maize. IV. Relationship to Reciprocal Recurrent Selection and Convergent Improvement. **Maydica** 40: 147-151.
- Matzinger, F. 1953. Comparison of three types of testers for the evaluation of inbred lines of corn. **Agron. J.** 45: 493-495.
- Mechii, M. R., J. W. Dudley, R. J. Lambert and G. F. Sprague, 1984. Inbreeding Depression, Inbred and Hybrid Grain Yield, and Other Traits of Maize Representing Three Eras. **Crop Sci.** 24: 545-549.
- Moll, R. H and C. W. Stuber. 1974. Quantitative genetics-empirical results relevant to plant breeding. **Agron. J.** 26: 277-313.

- Motto, M and R. H. Moll. 1983. Prolificacy in maize. **Maydica** 28: 53-76.
- Ouanklin, T and K. Samphantharak. 2002. Screening methods for high yielding corn inbreds in honeycomb design and performance of their hybrid combinations. **Kasetsart J. (Nat. Sci.)** 2003.
- Penny, L. H., W. A. Russell and G. F. Sprague. 1962. Types of gene action in yield heterosis in maize. **Crop Sci.** 2: 341-344.
- Russell, W. A and S. A. Eberhart. 1975. Hybrid performance of selected maize lines from reciprocal recurrent selection and testcross selection program. **Crop Sci.** 15: 1-4.
- Shebeski, L. H. 1967. **Wheat and breeding.** pp 253-272. *In* K. F. Neilson, ed. Proc. Canadian Centennial Wheat Symposium. Western Co-operative Fertilizer Limited. Modern Press Saskatchewan.
- Shull, G. H. 1908. **The composition of a field of maize.** Am Breed. Assoc. Rep. 4: 296-301.
- Shull, G. H. 1952. Beginning of the heterosis concept. pp 14-48. *In* J. W. Gowen (ed). **Heterosis.** Iowa State College Press Ames.
- Smith, O. S. 1983. Evaluation of recurrent selection in BSSS, BSCB1 and BS13 Maize populations. **Crop Sci.** 23: 35-40.
- Sneep, J. 1977. Selection for yield in early generation of self-fertilizing crops. **Euphytica** 26: 27-30.
- Sprague, G. F and P. A. Miller. 1950. A suggestion for evaluating current concepts of the genetic mechanism heterosis of corn. **Agron. J.** 42: 161-162.

- Sprague, G. F. 1964. Early testing and recurrent selection. pp. 400-417. *In* J. W. Gowen (ed). **Heterosis**. Hafner publ. Company, New York.
- Sprague, G. F and S. A. Eberhart. 1976. **Corn breeding**. pp. 305-362. *In* Corn and Corn Improvement. G. F. Sprague, ed. Am. Soc. Agron. Madison.
- Tave, D. 1995. Selective breeding programmes for medium-sized fish farms. **Fisheries Technical Paper**. No. 352. FAO. Rome.
- Tollenaar, M. 1991. Physiological basis of genetic improvement of maize hybrids in Ontario from 1959 to 1988. **Crop Sci**. 31: 119-124
- Tokatlidis, I. S., M. Koutsika-Sotiriou, A. C. Fasoulas and A. S. Tsaftaris. 1998. Improving maize hybrids for potential yield per plant. **Maydica** 43: 123-129.
- Tokatlidis, I. S., M. Koutsika-Sotiriou and A. C. Fasoulas. 1999. Load of deleterious genes and stability of performance in maize. **Maydica** 44: 127-132.
- Tokatlidis, I. S., M. Koutsika-Sotiriou and A. C. Fasoulas. 2001. The Development of density-independent hybrid in maize. **Maydica** 46: 21-25.
- Tracy, W. F. 1994. Sweet corn. pp. 147-187. *In* **Specialty corn**. A. R. Hallauer (ed). CRC press, Inc.
- Tracy, W. F. 1997. History, Genetics, and Breeding of Supersweet (*shrunken2*) Sweet Corn. **Plant Breeding Review** 14: 189-236.
- Tracy, W. F. 2001. Sweet corn. pp. 155-197. *In* **Specialty corn**. A. R. Hallauer (ed). CRC press, Inc.
- Troyer, A. F and R. W. Rosenbrook. 1983. Utility of higher plant densities for corn performance testing. **Crop Sci**. 23: 863-867.

- Troyer, A. F. 2001. Temperate corn background, behaviour and breeding. pp. 393-466. *In* **Specialty Corn**. A. R. Hallauer (ed). CRC press, Inc.
- Utz, H. F. 1984. Calculating and maximizing the gain from selection. **Vortr. Pflanzenzuechtg** 7: 30-40.
- Vasal, S. K and B. S. Dhillon. 1997. Recurrent selection methods based on evaluation cum-recombination block. **Plant Breeding Review** 14: 139-164.
- Well, H. E., J. A. Fuentes and A. H. Corzo. 1957. Race of maize in central America, Pub.511 **Nat. Acad. Sci.** Nat. Res. Council Washington D C.
- Westgate, M. E and P. Bassetti. 1990. Heat and drought stress in corn: What really happens to the corn plant at pollination. **Proc. 45th annual corn and sorghum research conference**: 12-28. Am. Seed Trade Assoc., Washington DC.
- Yan, W and D. H. Wallace. 1995. Breeding for negatively associated traits. **Plant Breeding Review** 13: 141-177.
- Yonezawa, K and H. Yamagata. 1978. On the number and size of cross combination in a breeding program of self-fertilizing crops. **Euphytica** 27: 113-116.

APPENDICES

Appendix Table 1 Some ear characteristic of intra-set hybrids ($S_3 \times S_3$), planted at Suwan Farm, Thailand in January, 2005 (dry season).

Rank order	Hybrid	Green ears/row	Usable ears/row	Usable ear weight	Unusable ear weight	Row configuration	Ear shape	Ear uniformity	Kernel color ^{2/}
		(kg/ear)				(1-5) ^{1/}			
1	L1 / L2	18.1	11.5	0.147	0.074	2.0	2.0	3.5	B
2	L1 / L3	23.8	20.4	0.150	0.086	2.0	2.0	3.5	B
3	L2 / L3	19.3	17.2	0.162	0.093	2.0	2.0	2.5	Y
4	L4 / L5	20.7	18.5	0.154	0.092	2.0	2.0	3.0	B
5	L4 / L6	22.3	19.4	0.142	0.067	2.0	2.0	3.5	B
6	L5 / L6	22.7	19.7	0.148	0.077	2.0	2.0	3.5	B
7	L7 / L8	23.6	21.0	0.172	0.093	2.0	2.0	3.5	Y
8	L7 / L9	22.1	19.2	0.166	0.087	2.0	2.0	3.5	Y
9	L8 / L9	22.4	17.9	0.168	0.070	2.0	2.0	2.5	Y
10	L10 / L11	23.0	15.7	0.145	0.086	2.0	2.0	3.0	Y
11	L10 / L12	20.3	18.6	0.170	0.075	2.0	2.0	3.0	B
12	L11 / L12	22.1	15.5	0.124	0.081	2.0	2.0	3.0	Y
13	L13 / L14	22.3	20.5	0.146	0.077	2.0	2.0	3.0	B
14	L13 / L15	21.5	19.6	0.168	0.071	2.0	2.0	3.5	B
15	L14 / L15	21.3	19.7	0.159	0.092	2.0	2.0	3.0	B
16	L16 / L17	18.3	14.2	0.165	0.075	2.0	2.0	3.5	Y
17	L16 / L18	22.0	16.5	0.168	0.076	2.5	2.0	3.5	Y
18	L17 / L18	22.1	19.7	0.153	0.083	2.0	2.0	3.5	Y
19	L19 / L20	21.5	19.6	0.178	0.092	2.0	2.0	3.5	Y
20	L19 / L21	19.7	16.9	0.177	0.072	2.0	2.0	3.5	Y
21	L20 / L21	18.0	13.2	0.144	0.083	2.0	2.0	3.5	Y
22	L22 / L23	19.5	18.8	0.170	0.050	2.0	2.0	3.0	Y
23	L22 / L24	19.5	19.3	0.162	0.100	2.0	2.0	2.5	Y
24	L23 / L24	19.4	18.3	0.161	0.045	2.0	2.0	3.0	Y
25	L25 / L26	21.7	18.4	0.177	0.096	2.0	2.0	2.5	Y
26	L25 / L27	23.6	20.4	0.185	0.080	2.0	2.0	2.5	Y
27	L26 / L27	22.6	18.9	0.163	0.081	2.5	2.0	2.5	Y
28	Check 1	23.2	22.1	0.203	0.100	2.0	2.0	1.5	Y
29	Check 2	28.2	27.4	0.160	0.100	2.0	2.0	1.5	B
30	Check 3	22.3	21.5	0.161	0.100	2.0	2.0	2.0	Y

^{1/} 1 was good; 5 was very bad; 2.5 was acceptable level

^{2/} Y was yellow; B was bicour

Appendix Table 2. Plant characteristic of intra-set hybrids ($S_3 \times S_3$), planted at Suwan Farm, Thailand in January, 2005 (dry season).

Rank order	Hybrid	Days to anthesis	Days to silking	Plant height	Ear height	Disease resistance	Plant uniformity	Root lodging	Stalk lodging
				(cm)	(cm)	(%)		(1-5) ^{2/}	
1	L1 / L2	58	60	152.8	69.7	60	2.5	1.0	1.0
2	L1 / L3	55	57	153.7	77.7	60	2.0	1.5	1.0
3	L2 / L3	55	57	155.7	79.7	70	3.0	1.0	1.0
4	L4 / L5	55	57	168.8	79.8	70	2.0	3.0	1.0
5	L4 / L6	54	56	176.5	89.8	90	2.0	2.5	1.0
6	L5 / L6	54	55	171.7	82.0	90	2.0	3.5	2.0
7	L7 / L8	52	54	174.8	85.7	90	3.0	3.5	2.0
8	L7 / L9	55	57	183.5	88.0	90	3.0	3.0	1.0
9	L8 / L9	54	56	177.0	81.5	70	2.0	3.5	1.0
10	L10 / L11	54	56	182.7	101.0	40	1.5	3.5	1.0
11	L10 / L12	55	57	184.3	86.2	50	2.5	1.5	1.0
12	L11 / L12	57	59	177.7	79.7	70	2.0	3.5	2.5
13	L13 / L14	52	54	173.5	83.8	90	3.0	1.5	1.0
14	L13 / L15	53	55	175.8	85.8	90	2.0	1.5	1.0
15	L14 / L15	53	55	168.7	80.7	90	2.5	1.0	1.0
16	L16 / L17	53	55	150.3	78.2	80	2.0	1.5	1.0
17	L16 / L18	53	55	170.7	82.5	70	2.5	3.0	1.0
18	L17 / L18	53	54	176.8	82.2	90	3.0	1.5	1.0
19	L19 / L20	54	55	165.3	78.7	80	3.0	1.0	1.0
20	L19 / L21	54	55	178.2	87.0	70	3.0	1.5	1.0
21	L20 / L21	56	59	165.5	84.3	40	3.0	1.5	1.0
22	L22 / L23	53	54	169.3	82.2	90	3.0	3.5	2.0
23	L22 / L24	52	53	172.5	90.3	90	1.5	1.0	1.0
24	L23 / L24	54	56	176.3	89.8	70	3.0	1.0	1.0
25	L25 / L26	54	56	177.0	93.2	90	3.0	1.0	1.0
26	L25 / L27	54	56	169.5	81.3	90	2.5	1.0	1.0
27	L26 / L27	54	56	157.5	75.3	70	2.5	2.5	1.0
28	Check 1	54	55	163.2	80.8	80	2.0	2.5	1.0
29	Check 2	53	54	167.0	86.8	90	1.5	3.0	1.0
30	Check 3	53	55	164.2	82.0	80	1.5	1.5	2.0

^{1/} Percent of free disease plants

^{2/} 1 was very good; 5 was very bad; 2.5 was acceptable level

Appendix Table 3 Some ear characteristic of testcross hybrids (S₃ x Insee₂), planted at Suwan Farm, Thailand in January, 2005 (dry season).

Rank order	Hybrid	Green ears/row	Usable ears/row	Usable ear weight	Unusable ear weight	Row configuration	Ear shape	Ear uniformity	Kernel color ^{2/}
		(kg/ear)				(1-5) ^{1/}			
1	Insee2/L ₁	22.5	17.3	0.192	0.100	2.0	2.5	2.5	Y
2	Insee2/L ₂	23.3	20.3	0.209	0.100	2.0	2.5	2.5	B
3	Insee2/L ₃	20.8	18.8	0.210	0.100	2.0	2.5	2.5	Y
4	Insee2/L ₄	22.8	21.5	0.198	0.067	2.0	2.5	2.0	B
5	Insee2/L ₅	22.3	20.8	0.216	0.067	2.5	2.5	2.5	B
6	Insee2/L ₆	22.3	20.3	0.210	0.050	2.0	2.0	2.0	Y
7	Insee2/L ₇	20.5	18.0	0.197	0.060	2.5	2.5	2.5	Y
8	Insee2/L ₈	22.8	17.3	0.189	0.050	2.5	2.5	2.5	Y
9	Insee2/L ₉	23.8	16.8	0.189	0.100	2.0	2.5	2.5	B
10	Insee2/L ₁₀	21.0	17.0	0.199	0.100	2.5	2.5	2.5	B
11	Insee2/L ₁₁	25.3	20.0	0.193	0.067	2.0	2.0	2.0	Y
12	Insee2/L ₁₂	20.5	16.5	0.190	0.080	2.0	2.5	2.5	Y
13	Insee2/L ₁₃	24.3	21.0	0.202	0.100	2.0	2.0	2.0	B
14	Insee2/L ₁₄	24.3	20.5	0.199	0.100	2.5	2.0	2.0	B
15	Insee2/L ₁₅	19.8	16.5	0.177	0.075	2.0	2.5	2.5	B
16	Insee2/L ₁₆	25.0	19.0	0.188	0.088	3.0	2.0	2.5	Y
17	Insee2/L ₁₇	23.3	22.3	0.182	0.100	2.5	2.0	2.0	Y
18	Insee2/L ₁₈	23.0	20.0	0.195	0.100	2.0	2.5	2.5	Y
19	Insee2/L ₁₉	21.0	18.5	0.205	0.100	2.5	2.5	2.5	Y
20	Insee2/L ₂₀	24.8	23.0	0.202	0.070	2.0	2.5	1.5	Y
21	Insee2/L ₂₁	21.5	18.5	0.206	0.067	2.5	2.5	2.5	Y
22	Insee2/L ₂₂	22.8	22.0	0.210	0.075	2.5	2.5	2.0	B
23	Insee2/L ₂₃	21.0	20.5	0.191	0.075	2.0	2.0	2.5	Y
24	Insee2/L ₂₄	24.0	22.0	0.217	0.080	2.5	2.0	1.5	B
25	Insee2/L ₂₅	20.3	16.8	0.201	0.086	2.5	2.5	2.5	B
26	Insee2/L ₂₆	23.8	22.3	0.195	0.100	2.0	2.0	2.0	Y
27	Insee2/L ₂₇	23.8	21.0	0.217	0.100	2.5	2.0	1.5	Y
28	Check 1	22.8	20.0	0.198	0.100	2.0	2.0	1.5	Y
29	Check 2	23.5	22.0	0.193	0.100	2.5	2.5	1.5	B
30	Check 3	17.3	13.8	0.205	0.080	2.5	2.5	2.0	Y

^{1/} 1 was good; 5 was very bad; 2.5 was acceptable level

^{2/} Y was yellow; B was bicolour

Appendix Table 4. Plant characteristic of Testcross hybrids ($S_3 \times \text{Insee}_2$), planted at Suwan Farm, Thailand in January, 2005 (dry season).

Rank order	Hybrid	Days to anthesis	Days to silking	Plant height	Ear height	Disease resistance	Plant uniformity	Root lodging	Stalk lodging	Husk cover
				(cm)	(cm)	(%) ^{1/}	(1-5) ^{2/}	(1-5) ^{2/}	(1-5) ^{2/}	
1	Insee2/L ₁	55	58	180.3	90.7	90	3.0	2.0	1.0	2.0
2	Insee2/L ₂	55	58	184.2	102.5	80	2.5	1.5	1.0	2.0
3	Insee2/L ₃	56	58	178.2	94.3	90	3.0	2.0	1.0	2.0
4	Insee2/L ₄	56	58	184.2	97.8	90	2.0	1.0	1.0	2.0
5	Insee2/L ₅	55	57	181.7	94.5	90	3.0	1.5	1.0	1.5
6	Insee2/L ₆	54	56	190.8	97.5	90	2.5	1.0	1.0	1.5
7	Insee2/L ₇	55	56	188.8	95.0	90	2.0	2.5	1.0	1.5
8	Insee2/L ₈	55	56	199.0	109.7	90	1.5	2.0	1.0	2.0
9	Insee2/L ₉	56	58	192.3	105.3	90	2.0	1.5	1.0	2.5
10	Insee2/L ₁₀	55	57	188.8	96.0	90	2.0	2.5	1.0	2.5
11	Insee2/L ₁₁	55	58	187.0	106.2	50	1.5	2.0	1.0	1.5
12	Insee2/L ₁₂	55	58	186.3	97.7	90	2.0	3.0	1.0	1.5
13	Insee2/L ₁₃	54	56	193.5	102.7	90	2.0	2.0	1.0	1.5
14	Insee2/L ₁₄	53	55	192.8	100.8	90	2.0	2.5	1.0	1.5
15	Insee2/L ₁₅	54	55	171.2	88.0	90	3.0	1.5	1.0	2.5
16	Insee2/L ₁₆	53	55	180.8	105.8	90	3.0	2.0	1.0	1.5
17	Insee2/L ₁₇	53	55	187.2	104.8	70	2.5	1.0	1.0	2.5
18	Insee2/L ₁₈	53	55	186.7	94.2	90	2.5	2.5	1.0	2.0
19	Insee2/L ₁₉	54	56	189.0	98.8	70	2.5	2.0	1.0	2.5
20	Insee2/L ₂₀	54	56	187.3	98.8	80	2.5	1.0	1.0	2.0
21	Insee2/L ₂₁	54	56	182.2	91.8	90	2.0	1.0	1.0	1.5
22	Insee2/L ₂₂	53	55	190.2	98.8	90	2.5	3.0	1.0	1.5
23	Insee2/L ₂₃	55	57	182.2	105.2	90	3.0	2.5	1.0	1.5
24	Insee2/L ₂₄	53	55	188.5	101.0	90	2.5	2.0	1.0	1.5
25	Insee2/L ₂₅	56	58	186.5	101.2	90	2.0	2.5	1.0	1.5
26	Insee2/L ₂₆	54	56	185.3	102.3	80	1.5	2.5	1.0	1.5
27	Insee2/L ₂₇	55	57	188.8	105.2	90	2.0	2.5	1.0	1.5
28	Check 1	55	57	182.3	98.8	70	1.5	2.0	1.0	2.0
29	Check 2	54	56	186.2	104.7	60	1.5	2.0	1.0	1.5
30	Check 3	55	57	192.2	97.7	70	2.0	3.0	1.0	2.5

^{1/} Percent of free disease plants

^{2/} 1 was very good; 5 was very bad; 2.5 was acceptable level

Appendix Table 5 Some ear characteristic of Intra-set testcross hybrids, planted at Suwan Farm, Thailand in January, 2005 (dry season).

Rank order	Hybrid	Green ears/row	Usable ears/row	Usable ear weight	Unusable ear weight	Row configuration	Ear shape	Ear uniformity	Kernel color ^{2/}
				(kg/ear)					
						(1-5) ^{1/}			
1	L ₁ /L ₃ //L ₁	23.3	13.5	0.127	0.085	2.5	2.5	3.0	B
2	L ₁ /L ₃ //L ₂	21.0	13.5	0.139	0.082	2.0	2.5	3.0	B
3	L ₁ /L ₃ //L ₃	18.3	12.3	0.145	0.062	2.5	2.5	3.0	Y
4	L ₅ /L ₆ //L ₄	18.8	11.5	0.136	0.079	2.5	2.5	2.5	B
5	L ₅ /L ₆ //L ₅	19.3	11.5	0.153	0.073	2.0	2.5	3.5	B
6	L ₅ /L ₆ //L ₆	22.3	15.0	0.146	0.087	2.0	2.0	2.5	B
7	L ₇ /L ₈ //L ₇	22.3	16.5	0.136	0.083	2.0	2.5	3.0	Y
8	L ₇ /L ₈ //L ₈	25.8	18.8	0.139	0.075	2.0	2.5	3.0	Y
9	L ₇ /L ₈ //L ₉	24.0	18.3	0.147	0.082	2.0	2.0	2.0	Y
10	L ₁₀ /L ₁₂ //L ₁₀	23.8	14.5	0.128	0.078	2.5	2.5	3.0	Y
11	L ₁₀ /L ₁₂ //L ₁₁	20.0	11.0	0.125	0.074	2.5	2.5	2.5	B
12	L ₁₀ /L ₁₂ //L ₁₂	16.8	10.3	0.153	0.093	2.0	2.5	2.5	Y
13	L ₁₃ /L ₁₅ //L ₁₃	24.0	18.5	0.146	0.093	2.0	2.0	2.5	B
14	L ₁₃ /L ₁₅ //L ₁₄	16.5	11.0	0.165	0.094	2.0	2.5	3.5	B
15	L ₁₃ /L ₁₅ //L ₁₅	21.3	15.5	0.156	0.073	2.5	2.5	2.5	B
16	L ₁₆ /L ₁₈ //L ₁₆	20.8	13.5	0.169	0.091	2.5	2.5	2.5	Y
17	L ₁₆ /L ₁₈ //L ₁₇	22.8	17.3	0.119	0.086	2.5	2.5	3.0	Y
18	L ₁₆ /L ₁₈ //L ₁₈	24.8	18.0	0.162	0.086	2.0	2.0	3.0	Y
19	L ₁₉ /L ₂₀ //L ₁₉	21.8	15.3	0.156	0.083	2.5	2.5	3.0	Y
20	L ₁₉ /L ₂₀ //L ₂₀	21.8	14.8	0.163	0.090	2.0	2.5	3.0	Y
21	L ₁₉ /L ₂₀ //L ₂₁	22.5	13.0	0.169	0.077	2.0	2.5	3.0	Y
22	L ₂₂ /L ₂₄ //L ₂₂	21.0	15.5	0.159	0.076	2.5	2.5	3.0	Y
23	L ₂₂ /L ₂₄ //L ₂₃	22.5	13.3	0.167	0.075	2.0	2.5	3.0	Y
24	L ₂₂ /L ₂₄ //L ₂₄	21.3	14.3	0.158	0.069	2.0	2.5	2.5	Y
25	L ₂₅ /L ₂₇ //L ₂₅	22.5	17.3	0.157	0.082	2.5	2.5	2.5	Y
26	L ₂₅ /L ₂₇ //L ₂₆	23.8	14.0	0.160	0.073	2.5	2.5	2.5	Y
27	L ₂₅ /L ₂₇ //L ₂₇	25.0	19.8	0.154	0.096	2.0	2.0	2.5	Y
28	Check 1	18.8	14.8	0.186	0.091	2.0	2.0	2.5	Y
29	Check 2	22.1	15.5	0.146	0.078	2.5	2.5	2.5	B
30	Check 3	22.6	17.3	0.160	0.087	2.0	2.5	2.5	Y
31	Hybrid ₃	19.5	16.0	0.218	0.115	1.5	1.5	1.5	Y
32	Insee ₂	19.5	12.8	0.159	0.087	2.0	2.0	2.0	Y

^{1/} 1 was good; 5 was very bad; 2.5 was acceptable level

^{2/} Y was yellow; B was bicolour

Appendix Table 6 Plant characteristic of Intra-set testcross hybrids, planted at Suwan Farm, Thailand in January, 2005 (dry season).

Rank order	Hybrid	Days to anthesis	Days to silking	Plant height		Disease resistance	Plant uniformity	Root lodging	Stalk lodging	Husk cover
				(cm)	(%) ^{1/}					
1	L ₁ /L ₃ /L ₁	51	53	139.7	67.9	70	2.5	1.5	1.5	2.0
2	L ₁ /L ₃ /L ₂	48	50	142.1	68.3	70	1.5	1.5	1.5	2.0
3	L ₁ /L ₃ /L ₃	48	50	137.3	67.9	60	3.0	1.5	1.5	2.0
4	L ₅ /L ₆ /L ₄	48	50	135.7	61.5	30	2.5	1.5	1.5	2.0
5	L ₅ /L ₆ /L ₅	47	49	140.8	64.2	80	2.0	1.5	1.5	1.5
6	L ₅ /L ₆ /L ₆	47	48	142.5	68.7	50	2.0	1.5	1.5	1.5
7	L ₇ /L ₈ /L ₇	45	47	151.4	73.8	50	1.5	1.5	1.5	1.5
8	L ₇ /L ₈ /L ₈	48	50	150.6	70.4	60	2.5	1.5	1.5	2.0
9	L ₇ /L ₈ /L ₉	47	56	156.3	78.4	90	2.5	1.5	1.5	2.5
10	L ₁₀ /L ₁₂ /L ₁₀	54	49	143.8	73.4	40	2.5	1.5	1.5	2.5
11	L ₁₀ /L ₁₂ /L ₁₁	48	50	146.2	70.4	40	2.0	1.5	1.5	1.5
12	L ₁₀ /L ₁₂ /L ₁₂	50	52	146.4	68.8	90	2.0	1.5	1.5	1.5
13	L ₁₃ /L ₁₅ /L ₁₃	45	48	140.8	68.5	90	1.5	1.5	1.5	1.5
14	L ₁₃ /L ₁₅ /L ₁₄	46	48	134.9	67.1	60	3.0	1.5	1.5	1.5
15	L ₁₃ /L ₁₅ /L ₁₅	46	48	138.6	67.2	30	2.0	1.5	1.5	2.5
16	L ₁₆ /L ₁₈ /L ₁₆	46	48	151.9	74.4	90	2.5	1.5	1.5	1.5
17	L ₁₆ /L ₁₈ /L ₁₇	46	48	146.6	73.3	90	2.0	1.5	1.5	2.5
18	L ₁₆ /L ₁₈ /L ₁₈	46	47	140.5	67.1	70	2.0	1.5	1.5	2.0
19	L ₁₉ /L ₂₀ /L ₁₉	47	48	143.6	72.5	80	2.0	1.5	1.5	2.5
20	L ₁₉ /L ₂₀ /L ₂₀	47	48	139.9	68.8	90	2.0	1.5	1.5	2.0
21	L ₁₉ /L ₂₀ /L ₂₁	49	52	139.0	68.5	90	1.5	1.5	1.5	1.5
22	L ₂₂ /L ₂₄ /L ₂₂	46	47	130.8	55.6	50	2.5	1.5	1.5	1.5
23	L ₂₂ /L ₂₄ /L ₂₃	45	46	129.4	61.0	80	2.0	1.5	1.5	1.5
24	L ₂₂ /L ₂₄ /L ₂₄	47	49	136.3	70.4	40	2.5	1.5	1.5	1.5
25	L ₂₅ /L ₂₇ /L ₂₅	47	49	147.3	67.3	90	2.0	1.5	1.5	1.5
26	L ₂₅ /L ₂₇ /L ₂₆	47	49	143.7	74.6	90	1.5	1.5	1.5	1.5
27	L ₂₅ /L ₂₇ /L ₂₇	48	50	154.8	76.9	90	1.5	1.5	1.5	1.5
28	Check 1	45	46	148.1	73.0	70	2.0	1.5	1.5	2.0
29	Check 2	45	47	147.4	69.8	70	2.0	1.5	1.5	1.5
30	Check 3	44	46	146.6	70.5	90	2.0	1.5	1.5	2.5
31	Hybrid ₃	46	58	138.3	85.0	90	1.5	1.5	1.5	2.5
32	Insee ₂	45	47	126.1	75.0	90	1.5	1.5	1.5	1.5

^{1/} Percent of free disease plants

^{2/} 1 was very good; 5 was very bad; 2.5 was acceptable level

Appendix Table 7 Some ear characteristic of Inter-set diallel crosses hybrids, planted at Suwan Farm, Thailand in January, 2005 (dry season).

Rank order	Hybrid	Green ears/row	Usable ears/row	Usable ear weight	Unusable ear weight	Row configuration	Ear shape	Ear uniformity	Kernel color ^{2/}
				(kg/ear)		(1-5) ^{1/}			
1	L ₁ /L ₃ //L ₅ /L ₆	19.5	16.3	0.161	0.088	2.0	2.0	2.0	B
2	L ₁ /L ₃ //L ₇ /L ₈	18.0	15.3	0.162	0.075	2.0	2.0	2.0	Y
3	L ₁ /L ₃ //L ₁₀ /L ₁₂	20.8	13.8	0.152	0.074	3.0	3.0	3.5	B
4	L ₁ /L ₃ //L ₁₃ /L ₁₅	21.0	16.3	0.162	0.089	2.5	2.5	2.5	B
5	L ₁ /L ₃ //L ₁₆ /L ₁₈	20.3	17.8	0.162	0.091	2.0	2.0	1.5	Y
6	L ₁ /L ₃ //L ₁₉ /L ₂₀	21.5	16.5	0.146	0.072	2.0	2.0	2.5	Y
7	L ₁ /L ₃ //L ₂₂ /L ₂₄	21.3	16.8	0.157	0.077	2.0	2.0	2.0	B
8	L ₁ /L ₃ //L ₂₅ /L ₂₇	21.3	18.5	0.178	0.048	2.0	2.0	2.0	Y
9	L ₅ /L ₆ //L ₇ /L ₈	21.0	16.5	0.187	0.078	1.5	1.5	3.0	Y
10	L ₅ /L ₆ //L ₁₀ /L ₁₂	22.0	16.8	0.159	0.080	2.0	2.0	2.5	B
11	L ₅ /L ₆ //L ₁₃ /L ₁₅	22.5	20.8	0.155	0.061	2.0	2.0	2.0	B
12	L ₅ /L ₆ //L ₁₆ /L ₁₈	21.3	19.3	0.194	0.081	2.0	2.0	2.0	Y
13	L ₅ /L ₆ //L ₁₉ /L ₂₀	21.8	18.5	0.167	0.068	2.0	2.0	2.0	B
14	L ₅ /L ₆ //L ₂₂ /L ₂₄	22.3	17.3	0.141	0.068	2.5	2.5	2.5	B
15	L ₅ /L ₆ //L ₂₅ /L ₂₇	20.3	17.8	0.192	0.085	2.0	2.0	2.0	Y
16	L ₇ /L ₈ //L ₁₀ /L ₁₂	20.8	17.5	0.164	0.075	2.0	2.0	1.5	Y
17	L ₇ /L ₈ //L ₁₃ /L ₁₅	20.8	18.8	0.193	0.100	1.5	1.5	1.5	B
18	L ₇ /L ₈ //L ₁₆ /L ₁₈	21.3	17.5	0.162	0.085	2.0	2.0	1.5	Y
19	L ₇ /L ₈ //L ₁₉ /L ₂₀	22.8	18.8	0.175	0.093	2.0	2.0	1.5	Y
20	L ₇ /L ₈ //L ₂₂ /L ₂₄	22.0	19.5	0.184	0.086	2.0	2.0	2.0	Y
21	L ₇ /L ₈ //L ₂₅ /L ₂₇	21.3	18.0	0.164	0.083	2.0	2.0	1.5	Y
22	L ₁₀ /L ₁₂ //L ₁₃ /L ₁₅	23.3	18.5	0.164	0.087	2.0	2.5	2.5	B
23	L ₁₀ /L ₁₂ //L ₁₆ /L ₁₈	23.8	21.0	0.187	0.077	2.0	2.0	1.5	B
24	L ₁₀ /L ₁₂ //L ₁₉ /L ₂₀	21.3	15.0	0.143	0.062	2.0	2.5	3.0	B
25	L ₁₀ /L ₁₂ //L ₂₂ /L ₂₄	22.5	17.8	0.161	0.083	2.0	2.0	2.5	B
26	L ₁₀ /L ₁₂ //L ₂₅ /L ₂₇	21.8	18.0	0.186	0.092	2.0	2.5	2.5	B
27	L ₁₃ /L ₁₅ //L ₁₆ /L ₁₈	23.5	20.8	0.186	0.075	2.0	2.0	2.0	B
28	L ₁₃ /L ₁₅ //L ₁₉ /L ₂₀	23.5	20.3	0.167	0.079	2.0	2.0	2.0	B
29	L ₁₃ /L ₁₅ //L ₂₂ /L ₂₄	26.3	22.5	0.151	0.083	2.0	2.5	3.0	B
30	L ₁₃ /L ₁₅ //L ₂₅ /L ₂₇	21.8	19.0	0.182	0.090	2.0	2.0	2.0	Y
31	L ₁₆ /L ₁₈ //L ₁₉ /L ₂₀	22.0	20.5	0.179	0.088	2.0	2.0	2.0	Y
32	L ₁₆ /L ₁₈ //L ₂₂ /L ₂₄	22.5	21.0	0.182	0.083	2.0	2.0	1.5	Y
33	L ₁₆ /L ₁₈ //L ₂₅ /L ₂₇	21.0	18.3	0.160	0.076	2.0	2.0	2.5	V
34	L ₁₉ /L ₂₀ //L ₂₂ /L ₂₄	20.5	14.3	0.160	0.088	2.0	2.0	3.0	B
35	L ₁₉ /L ₂₀ //L ₂₅ /L ₂₇	20.5	17.0	0.169	0.079	2.0	2.0	2.5	Y
36	L ₂₂ /L ₂₄ //L ₂₅ /L ₂₇	22.0	19.3	0.189	0.088	2.0	2.0	2.0	Y
37	Check 1	21.0	17.8	0.183	0.071	1.5	1.5	1.5	Y
38	Check 2	26.5	20.1	0.155	0.079	2.0	2.0	2.5	B
39	Check 3	21.0	17.8	0.171	0.077	2.0	2.5	2.0	Y
40	Hybrid ₃	20.0	16.0	0.244	0.115	1.0	1.0	1.0	Y
41	Insee ₂	19.8	16.0	0.183	0.091	2.0	2.0	1.5	Y

^{1/} 1 was good; 5 was very bad; 2.5 was acceptable level

^{2/} Y was yellow; B was bicolour

Appendix Table 8 Plant characteristic of Inter-set diallel cross hybrids, planted at Suwan Farm, Thailand in January, 2005 (dry season).

Rank order	Hybrid	Days to anthesis	Days to silking	Plant height	Ear height	Disease resistance	Plant uniformity	Root lodging	Stalk lodging	Husk cover
				(cm)	(cm)	(%) ^{1/}		(1-5) ^{2/}		
1	L ₁ /L ₃ //L ₅ /L ₆	47	49	140.4	73.6	90	2.8	2.5	1.5	1.5
2	L ₁ /L ₃ //L ₇ /L ₈	47	49	150.0	77.2	80	2.5	2.5	1.5	1.5
3	L ₁ /L ₃ //L ₁₀ /L ₁₂	46	49	143.3	75.5	70	2.5	2.5	1.5	1.5
4	L ₁ /L ₃ //L ₁₃ /L ₁₅	46	48	143.5	82.3	80	2.5	2.5	1.5	1.5
5	L ₁ /L ₃ //L ₁₆ /L ₁₈	46	48	136.3	76.1	100	2.5	2.5	1.5	1.5
6	L ₁ /L ₃ //L ₁₉ /L ₂₀	45	48	137.7	76.7	70	2.5	2.5	1.5	1.5
7	L ₁ /L ₃ //L ₂₂ /L ₂₄	45	47	132.6	76.3	90	2.3	2.5	1.5	1.5
8	L ₁ /L ₃ //L ₂₅ /L ₂₇	47	49	137.8	73.3	90	2.5	2.0	1.5	1.5
9	L ₅ /L ₆ //L ₇ /L ₈	46	48	156.3	79.8	80	2.3	1.5	1.5	1.5
10	L ₅ /L ₆ //L ₁₀ /L ₁₂	47	49	153.4	83.1	80	2.8	1.5	1.5	1.5
11	L ₅ /L ₆ //L ₁₃ /L ₁₅	45	48	138.2	76.6	90	2.3	2.5	1.5	1.5
12	L ₅ /L ₆ //L ₁₆ /L ₁₈	46	48	154.3	84.7	80	2.8	1.0	1.5	2.0
13	L ₅ /L ₆ //L ₁₉ /L ₂₀	47	49	152.8	83.8	90	2.5	1.5	1.5	1.5
14	L ₅ /L ₆ //L ₂₂ /L ₂₄	46	48	128.0	68.8	60	2.5	1.0	1.5	1.5
15	L ₅ /L ₆ //L ₂₅ /L ₂₇	45	47	155.7	84.3	70	2.8	1.0	1.5	1.5
16	L ₇ /L ₈ //L ₁₀ /L ₁₂	46	49	153.2	88.9	90	3.0	1.0	1.5	2.0
17	L ₇ /L ₈ //L ₁₃ /L ₁₅	46	48	155.0	88.3	100	2.5	1.0	1.5	3.0
18	L ₇ /L ₈ //L ₁₆ /L ₁₈	47	50	151.7	89.0	100	1.8	1.0	1.5	2.0
19	L ₇ /L ₈ //L ₁₉ /L ₂₀	48	50	158.0	91.7	80	2.5	1.0	1.5	1.5
20	L ₇ /L ₈ //L ₂₂ /L ₂₄	46	48	165.0	90.7	100	2.0	1.0	1.5	1.5
21	L ₇ /L ₈ //L ₂₅ /L ₂₇	46	49	152.5	85.5	90	2.3	2.0	1.5	1.5
22	L ₁₀ /L ₁₂ //L ₁₃ /L ₁₅	47	49	146.1	82.6	100	3.0	2.0	1.5	2.0
23	L ₁₀ /L ₁₂ //L ₁₆ /L ₁₈	47	49	146.9	85.8	100	2.0	2.0	1.5	2.0
24	L ₁₀ /L ₁₂ //L ₁₉ /L ₂₀	48	50	142.5	80.3	90	2.3	2.0	1.5	2.0
25	L ₁₀ /L ₁₂ //L ₂₂ /L ₂₄	45	47	147.1	84.6	70	2.5	2.0	1.5	1.5
26	L ₁₀ /L ₁₂ //L ₂₅ /L ₂₇	45	48	147.2	78.3	100	2.8	2.0	1.5	2.5
27	L ₁₃ /L ₁₅ //L ₁₆ /L ₁₈	45	47	147.5	81.7	100	2.5	2.0	1.5	2.0
28	L ₁₃ /L ₁₅ //L ₁₉ /L ₂₀	46	48	144.8	80.7	100	2.8	2.0	1.5	1.5
29	L ₁₃ /L ₁₅ //L ₂₂ /L ₂₄	45	47	132.9	69.6	100	1.8	1.0	1.5	1.5
30	L ₁₃ /L ₁₅ //L ₂₅ /L ₂₇	45	48	146.1	82.5	100	2.5	2.0	1.5	1.5
31	L ₁₆ /L ₁₈ //L ₁₉ /L ₂₀	45	47	152.5	82.9	100	2.0	2.0	1.5	1.5
32	L ₁₆ /L ₁₈ //L ₂₂ /L ₂₄	45	47	147.1	79.2	100	1.8	2.0	1.5	1.5
33	L ₁₆ /L ₁₈ //L ₂₅ /L ₂₇	46	48	152.9	86.3	100	2.3	2.0	1.5	1.5
34	L ₁₉ /L ₂₀ //L ₂₂ /L ₂₄	46	48	141.3	79.6	100	1.8	2.0	1.5	1.5
35	L ₁₉ /L ₂₀ //L ₂₅ /L ₂₇	46	48	141.3	80.4	100	2.0	2.0	1.5	1.5
36	L ₂₂ /L ₂₄ //L ₂₅ /L ₂₇	45	47	151.3	88.3	100	2.0	2.0	1.5	2.5
37	Check 1	46	48	145.6	81.9	100	1.8	2.5	1.5	2.0
38	Check 2	47	49	141.3	76.1	80	1.9	2.5	1.5	1.5
39	Check 3	46	48	144.3	77.4	90	2.5	2.5	1.5	2.0
40	Hybrid ₃	48	51	138.3	85.0	90	1.5	1.0	1.5	1.5
41	Insee ₂	47	49	126.1	75.0	90	1.5	1.0	1.5	2.0

^{1/} Percent of free disease plants

^{2/} 1 was very good; 5 was very bad; 2.5 was acceptable level

Appendix Table 9 Green ear yield of Inter-set diallel cross hybrids planted at Suwan Farm, Thailand in July 2005 (rainy season).

Pedigree	L ₁ /L ₃	L ₅ /L ₆	L ₇ /L ₈	L ₁₀ /L ₁₂	L ₁₃ /L ₁₅	L ₁₆ /L ₁₈	L ₁₉ /L ₂₀	L ₂₂ /L ₂₄	L ₂₅ /L ₂₇	Total	Mean
L ₁ /L ₃		10.93 ^{h-1*}	10.33 ^{j-1}	10.13 ^{k-1}	11.33 ^{e-1}	12.07 ^{c-1}	10.07 ^{k-1}	11.13 ^{f-1}	13.00 ^{c-k}	89.00	11.13
L ₅ /L ₆			12.47 ^{c-1}	11.00 ^{g-1}	12.13 ^{c-1}	14.00 ^{b-g}	12.33 ^{c-1}	10.40 ⁱ⁻¹	13.40 ^{b-i}	96.67	12.08
L ₇ /L ₈				12.20 ^{c-1}	14.13 ^{a-f}	12.20 ^{c-1}	13.07 ^{c-k}	14.27 ^{a-e}	12.60 ^{c-1}	101.27	12.66
L ₁₀ /L ₁₂					13.07 ^{c-k}	15.00 ^{a-c}	9.67 ^l	11.60 ^{d-l}	13.80 ^{b-h}	96.47	12.06
L ₁₃ /L ₁₅						16.27 ^{a-b}	13.20 ^{c-j}	13.87 ^{b-h}	14.53 ^{a-d}	108.53	13.57
L ₁₆ /L ₁₈							13.87 ^{b-h}	14.27 ^{a-e}	12.73 ^{c-k}	110.40	13.80
L ₁₉ /L ₂₀								10.33 ^{j-1}	11.80 ^{d-l}	94.33	11.79
L ₂₂ /L ₂₄									14.33 ^{a-e}	100.20	12.53
L ₂₅ /L ₂₇										106.20	13.28
Check1	Agsh ₂ 201/Agsh ₂ 309		12.27 ^{c-1}								
Check2	Agsh ₂ 303/Agsh ₂ 309		12.83 ^{c-k}								
Check3	Agsh ₂ 201/Agsh ₂ 318		12.00 ^{c-1}								
Check4	Insee2		13.47 ^{b-h}								
Check5	Hybrid3		16.87 ^a								
Mean	12.66										
CV(%)	13.60										

* Means within either a column or a row followed by the same letter are not significantly different at $P \leq 0.05$ according to Duncan's multiple range test.

Appendix Table 10 Husked ear yield of Inter-set diallel cross hybrids planted at Suwan Farm, Thailand in July 2005 (rainy season).

Pedigree	L ₁ /L ₃	L ₅ /L ₆	L ₇ /L ₈	L ₁₀ /L ₁₂	L ₁₃ /L ₁₅	L ₁₆ /L ₁₈	L ₁₉ /L ₂₀	L ₂₂ /L ₂₄	L ₂₅ /L ₂₇	Total	Mean
L ₁ /L ₃		7.00 ^{g-l*}	6.57 ^{h-l}	5.57 ^l	7.00 ^{g-l}	7.70 ^{d-k}	6.40 ^{i-l}	7.03 ^{g-l}	8.77 ^{a-g}	56.03	7.00
L ₅ /L ₆			8.20 ^{b-j}	7.10 ^{f-l}	8.53 ^{a-i}	9.97 ^{a-c}	8.27 ^{b-i}	6.47 ^{i-l}	9.13 ^{a-g}	64.67	8.08
L ₇ /L ₈				7.67 ^{d-l}	9.70 ^{a-e}	7.53 ^{e-l}	8.77 ^{a-g}	9.57 ^{a-e}	7.90 ^{c-j}	65.90	8.24
L ₁₀ /L ₁₂					8.07 ^{c-j}	10.43 ^a	5.73 ^{k-l}	7.63 ^{d-l}	8.90 ^{a-g}	61.10	7.64
L ₁₃ /L ₁₅						10.30 ^{a-b}	9.00 ^{a-g}	9.07 ^{a-g}	9.23 ^{a-f}	70.90	8.86
L ₁₆ /L ₁₈							9.77 ^{a-d}	10.27 ^{a-b}	7.80 ^{d-k}	73.77	9.22
L ₁₉ /L ₂₀								6.07 ^{j-l}	7.67 ^{d-l}	61.67	7.71
L ₂₂ /L ₂₄									9.70 ^{a-e}	65.80	8.23
L ₂₅ /L ₂₇										69.10	8.64
Check1	Agsh ₂ 201/Agsh ₂ 309		8.68 ^{a-h}								
Check2	Agsh ₂ 303/Agsh ₂ 309		8.32 ^{a-i}								
Check3	Agsh ₂ 201/Agsh ₂ 318		8.12 ^{c-j}								
Check4	Insee2		7.80 ^{d-k}								
Check5	Hybrid3		10.43 ^a								
Mean	8.24										
CV(%)	15.10										

* Means within either a column or a row followed by the same letter are not significantly different at $P \leq 0.05$ according to Duncan's multiple range test.

Appendix Table 11 Percentage of marketable ears of Inter-set diallel cross hybrids planted at Suwan Farm, Thailand in July 2005 (rainy season).

Pedigree	L ₁ /L ₃	L ₅ /L ₆	L ₇ /L ₈	L ₁₀ /L ₁₂	L ₁₃ /L ₁₅	L ₁₆ /L ₁₈	L ₁₉ /L ₂₀	L ₂₂ /L ₂₄	L ₂₅ /L ₂₇	Total	Mean
L ₁ /L ₃		83.96 ^{a-e*}	85.23 ^{a-d}	66.67 ^g	77.10 ^{c-g}	87.48 ^{a-d}	76.60 ^{c-g}	79.31 ^{b-g}	86.58 ^{a-d}	642.94	80.37
L ₅ /L ₆			78.77 ^{b-g}	75.96 ^{d-g}	92.53 ^{a-b}	90.43 ^{a-c}	85.25 ^{a-d}	77.47 ^{c-g}	87.49 ^{a-d}	671.85	83.98
L ₇ /L ₈				84.45 ^{a-d}	90.35 ^{a-c}	81.97 ^{a-f}	82.12 ^{a-f}	88.58 ^{a-d}	84.58 ^{a-d}	676.04	84.51
L ₁₀ /L ₁₂					79.89 ^{a-g}	88.65 ^{a-d}	70.51 ^{e-g}	78.68 ^{b-g}	82.67 ^{a-f}	627.47	78.43
L ₁₃ /L ₁₅						88.83 ^{a-d}	85.79 ^{a-d}	85.69 ^{a-d}	87.79 ^{a-d}	687.97	86.00
L ₁₆ /L ₁₈							93.62 ^a	93.65 ^a	87.34 ^{a-d}	711.97	89.00
L ₁₉ /L ₂₀								69.20 ^{f-g}	83.11 ^{a-e}	646.20	80.77
L ₂₂ /L ₂₄									87.95 ^{a-d}	660.54	82.57
L ₂₅ /L ₂₇										687.50	85.94
Check1	Agsh ₂ 201/Agsh ₂ 309		86.01 ^{a-d}								
Check2	Agsh ₂ 303/Agsh ₂ 309		77.10 ^{c-g}								
Check3	Agsh ₂ 201/Agsh ₂ 318		86.14 ^{a-d}								
Check4	Insee2		80.90 ^{a-f}								
Check5	Hybrid3		79.85 ^{a-g}								
Mean	83.32										
CV(%)	9.55										

* Means within either a column or a row followed by the same letter are not significantly different at $P \leq 0.05$ according to Duncan's multiple range test.

Appendix Table 12 Percentage of husked ear yield of Inter-set diallel cross hybrids planted at Suwan Farm, Thailand in July 2005 (rainy season).

Pedigree	L ₁ /L ₃	L ₅ /L ₆	L ₇ /L ₈	L ₁₀ /L ₁₂	L ₁₃ /L ₁₅	L ₁₆ /L ₁₈	L ₁₉ /L ₂₀	L ₂₂ /L ₂₄	L ₂₅ /L ₂₇	Total	Mean
L ₁ /L ₃		63.85 ^{b-f*}	63.70 ^{b-f}	54.82 ^g	61.95 ^{c-f}	63.68 ^{b-f}	63.72 ^{b-f}	63.62 ^{b-f}	67.39 ^{a-d}	502.73	62.84
L ₅ /L ₆			65.73 ^{a-c}	64.65 ^{a-f}	70.36 ^{a-b}	71.09 ^{a-b}	67.21 ^{a-d}	62.17 ^{c-f}	67.98 ^{a-d}	533.04	66.63
L ₇ /L ₈				62.66 ^{c-f}	68.27 ^{a-d}	61.77 ^{d-g}	67.23 ^{a-d}	67.03 ^{a-d}	62.33 ^{c-f}	518.72	64.84
L ₁₀ /L ₁₂					62.15 ^{c-f}	69.55 ^{a-c}	59.15 ^{e-g}	65.72 ^{a-e}	64.27 ^{a-f}	502.97	62.87
L ₁₃ /L ₁₅						63.66 ^{b-f}	68.33 ^{a-d}	65.35 ^{a-f}	63.74 ^{b-f}	523.81	65.48
L ₁₆ /L ₁₈							70.64 ^{a-b}	71.74 ^a	61.42 ^{d-g}	533.55	66.69
L ₁₉ /L ₂₀								58.48 ^{e-g}	65.04 ^{a-f}	519.8	64.98
L ₂₂ /L ₂₄									67.94 ^{a-d}	522.05	65.26
L ₂₅ /L ₂₇										520.11	65.01
Check1	Agsh ₂ 201/Agsh ₂ 309		70.63 ^{a-b}								
Check2	Agsh ₂ 303/Agsh ₂ 309		64.93 ^{a-f}								
Check3	Agsh ₂ 201/Agsh ₂ 318		67.55 ^{a-d}								
Check4	Insee2		57.82 ^{f-g}								
Check5	Hybrid3		61.78 ^{d-g}								
Mean	64.90										
CV(%)	6.73										

* Means within either a column or a row followed by the same letter are not significantly different at $P \leq 0.05$ according to Duncan's multiple range test.

Appendix Table 13 Recovery percentage of Inter-set diallel cross hybrids planted at Suwan Farm, Thailand in July 2005 (rainy season).

Pedigree	L ₁ /L ₃	L ₅ /L ₆	L ₇ /L ₈	L ₁₀ /L ₁₂	L ₁₃ /L ₁₅	L ₁₆ /L ₁₈	L ₁₉ /L ₂₀	L ₂₂ /L ₂₄	L ₂₅ /L ₂₇	Total	Mean
L ₁ /L ₃		41.56 ^{a-g*}	36.55 ^{c-j}	33.13 ^{h-j}	37.04 ^{b-j}	37.32 ^{b-j}	38.02 ^{b-j}	41.95 ^{a-f}	38.48 ^{a-j}	304.05	38.01
L ₅ /L ₆			37.70 ^{b-j}	41.08 ^{a-g}	39.43 ^{a-i}	43.75 ^{a-c}	37.46 ^{b-j}	37.26 ^{b-j}	40.30 ^{a-h}	318.54	39.82
L ₇ /L ₈				36.60 ^{c-j}	43.21 ^{a-d}	35.35 ^{e-j}	42.02 ^{a-f}	44.42 ^{a-b}	36.08 ^{d-j}	311.93	38.99
L ₁₀ /L ₁₂					39.43 ^{a-i}	42.97 ^{a-d}	34.38 ^{g-j}	43.60 ^{a-c}	36.50 ^{c-j}	307.69	38.46
L ₁₃ /L ₁₅						41.32 ^{a-g}	43.58 ^{a-c}	42.72 ^{a-e}	32.94 ^{i-j}	319.67	39.96
L ₁₆ /L ₁₈							40.26 ^{a-i}	45.67 ^a	33.47 ^{h-j}	320.11	40.01
L ₁₉ /L ₂₀								37.55 ^{b-j}	39.35 ^{a-i}	312.62	39.08
L ₂₂ /L ₂₄									42.36 ^{a-e}	335.53	41.94
L ₂₅ /L ₂₇										299.48	37.44
Check1	Agsh ₂ 201/Agsh ₂ 309		43.45 ^{a-d}								
Check2	Agsh ₂ 303/Agsh ₂ 309		41.51 ^{a-g}								
Check3	Agsh ₂ 201/Agsh ₂ 318		41.17 ^{a-g}								
Check4	Insee2		31.50 ^j								
Check5	Hybrid3		34.83 ^{f-j}								
Mean	39.20										
CV(%)	10.74										

* Means within either a column or a row followed by the same letter are not significantly different at $P \leq 0.05$ according to Duncan's multiple range test.