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NAME: Mr. Myint Soe

THIS THESIS HAS BEEN ACCEPTED BY

____________________ **THESIS ADVISOR**

(Associate Professor Prapa Sripichitt, D.Agr.)

____________________ **THESIS CO-ADVISOR**

(Associate Professor Wanchai Chanprasert, Ph.D.)

____________________ **THESIS CO-ADVISOR**

(Assistant Professor Vipa Hongtrakul, Ph.D.)

____________________ **PROGRAM CHAIRMAN**

(Associate Professor Yingyong Paisooksantivatana,Ph.D.)

APPROVED BY THE GRADUATE SCHOOL ON ____________________

____________________ **DEAN**

(Associate Professor Gunjana Theeragool, D.Agr.)

THESIS

INHERITANCE OF FIELD WEATHERING RESISTANCE IN SOYBEAN [*Glycine max* (L.) Merrill]

MYINT SOE

A Thesis Submitted in Partial Fulfillment of
the Requirements for the Degree of
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A major obstacle to soybean production in the tropics is the difficulty in producing high quality seed because of adverse environmental conditions. For example, high temperature and relative humidity during the final stages of seed maturation are not conducive to production of high quality seed. Soybean seeds deteriorate faster than those of most other crops especially under tropical condition. The deterioration of seed vigor as well as viability due to high temperature and relative humidity during the post-maturation and pre-harvest period is referred to as field weathering. The purpose of this study was to investigate the inheritance of field weathering resistance in some soybean varieties.

Commercial variety *Chiangmai 60* which was susceptible to field weathering and two field weathering resistant varieties *GC 10848* and *Kalitur* were grown and hybridized in the greenhouse at the Department of Agronomy, Kasetsart University. The F_1 hybrid seeds and their parental varieties were planted in the greenhouse to produce F_2 seeds. Parental varieties, F_1 hybrids and F_2 progenies were grown in the experimental field during dry season of 2008 at the National Corn and Sorghum Research Center, Pakchong District, Nakhon Rachasima Province. At physiological maturity, soybean pods were harvested, threshed and subjected to accelerated aging (AA) test, electrical conductivity (EC) test, seed coat percentage and seed weight measurement. Field weathering resistance of the parental plants, F_1 hybrids and F_2 progenies were evaluated using germination percentages after AA test, EC values of seed leachate, seed coat percentages and seed weight. The inheritance of field weathering resistance in soybean was determined by dominance percentages of F_1 hybrids and the frequency distribution of F_2 progenies for the germination percentages after AA test, EC values of seed leachate, seed coat percentages and seed weight of the two soybean crosses. The finding revealed that field weathering resistance was controlled by polygene with partial dominance.

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Myint Soe

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INHERITANCE OF FIELD WEATHERING RESISTANCE IN SOYBEAN [*Glycine max* (L.) Merrill]

INTRODUCTION

Soybean is produced primarily for seed protein and oil. Soybean seed contains approximately 37-41% protein, 18-21% oil, 30-40% carbohydrate and 4-5% ash (Hulse, 1996). Secondly, it has a capacity to use the atmospheric nitrogen through biological nitrogen fixation process with symbiosis effect of its root and nodulating bacteria. Soybean is also the lowest-cost producer of vegetable oil. It is one of the world's leading sources of vegetable oil and plant protein, both of which are very well adapted to the nourishment of human beings (Scott and Aldrich, 1983).

Historically, soybean was produced in the northern regions of the temperate climatic zones of the world, where environmental stresses were relatively minimal. However, as the world demand for vegetable oil and protein continues to increase, soybean production has been spreaded rapidly into the hot and humid areas, and more recently into the tropical regions (Moore, 1966; TeKrony *et al*., 1980a).In 2006-2007, soybean production were increased 57.5-56.4% among 397.2-390.1 MMT (million metric ton) of total world oilseed production. During these years, world soybean meal consumptions were 151.3-160.2 MMT, as the largest amount among 223.4-231.1 MMT of the total world meal consumptions. World soybean oil consumptions were accounted to 35.7-38.4 MMT as the second largest amount among 122.0-128.2 MMT of the total world vegetable oil consumptions. However, these amounts were nearly the same as 38.1-40.8 MMT of world palm oil consumptions as the largest amount of the total (Soy Stats, 2007; 2008).

A major obstacle to the expansion of soybean production to new areas of the tropics is the difficulty in producing high quality seed. In tropical conditions, high temperature and relative humidity during the final stages of seed maturation are not conducive to production of high quality seed to establish acceptable stands (Paschal and Ellis, 1978). Soybean seeds deteriorated faster than those of most other crops, especially under tropical condition (Delouche and Baskin, 1973; Priestley *et al*., 1985). The process of deterioration in seed quality occurs between the stages of the post-maturation and pre-harvest period is referred to as field weathering (TeKrony *et al*., 1980a).

Field weathering is a major problem for soybean production in the humid subtropics and tropics. The quality of soybean seeds at harvest time depends heavily on the field weathering conditions during the development, maturation and storage of the seeds on the plant. The severity and limitations of weathering imposed on seed quality generally increase from cool to warm areas. The worst situation is in the humid subtropics and tropics. The quality of seeds produced generally is low and seed deterioration continues at a rapid rate during the storage time because of high temperature and humidity of the environments (Bhatia *et al*., 1993).

Field weathering of soybean seeds can be overcome by enhancing field management such as carefully matching the maturity of cultivar with rainfall patterns and planting date (Green *et al*., 1965; Nangju *et al*., 1980; Franca Neto *et al*., 1994), adjusting latitude and specific seed production region (TeKrony *et al*., 1980b) and using foliar fungicide and defoliants (Andreoli and Ebeltoft, 1979; Costa *et al*., 1983; and Franca Neto *et al*., 1984). Besides, using the field weathering resistant variety can reduce seed deterioration. Specifically, field weathering resistant variety allows the farmers to grow soybean in both rainy and dry seasons (Pascal and Ellis, 1978; Wien and Kueneman, 1981). Varietal differences have been identified for resistance to field weathering and deterioration during storage (Potts *et al*., 1978; Ndimande *et al*. 1981; Minor and Pascal, 1982).

Of these, breeding new resistance varieties is the most important and essential ways to solve the field weathering problem because most of commercial soybean varieties are susceptible to field weathering. Besides, field weathering resistant varieties are low in grain yield and market demand. Hard seed coat attributed to field weathering resistance is not desired in commercial soybean varieties because it causes un-uniform germination and emergence. Small seed size and black seed coat for field weathering resistance are also not favored in the market even they have no influence on yield. Special carefulness is needed to use these characteristics in breeding program (Hartwig and Edwards, 1970; Hill *et al*., 1986a; 1986b; Hartwig and Potts, 1987).

At present, the field weathering breeding is limited by the lack of genetic information. Inheritance of field weathering resistance should be investigated to facilitate the breeding process for improving field weathering resistant variety. Just a little work has been done on the inheritance of field weathering resistance such as the works of Unander *et al*. (1983), Dechkrong (2006) and Changrong *et al.* (2006, 2007a). However, their works are not in detail. Therefore, it is a very important need to know the inheritance of field weathering resistance for future breeding program in soybean.

OBJECTIVE

The objective of this study was to determine the inheritance of field weathering resistance in some soybean varieties.

LITERATURE REVIEW

Origin and distribution of soybean

Soybean is one of the oldest cultivated crops. The first record of soybean goes as far back as 2500 B.C. in China and Manchuria (Morse, 1950). From then on, soybean was domesticated in the eastern half of China and spreaded into Japan, Korea and the rest of Southeast Asia. Soybean was introduced to Europe in 1712 by Englebert Kaempfer, a German botanist who had studied in Japan. Later, Swedish botanist Carl von Linne made the first scientific study of soybean in the West and named it *Glycine max* because of the unusually large nitrogen-producing nodules on its roots. Soybean was first grown in America in 1765 and in Thailand in 1931 (Hymowitz and Harlan, 1983; Probst and Judd, 1973). Now, soybean has a very broad distribution and is cultivated at broadly diverse geographical locations and under many different growing conditions, particularly in the America and Asia (Soy Stats, 2005).

Soybean belongs to the family Leguminosae, subfamily Papilionoideae, tribe Phaseoleae and genus *Glycine*. The *Glycine* genus contains two subgenera, *Glycine* and *Soja* (Gazzoni, 1994). The genus presently includes six perennial in the subgenus *Glycine* and two annual species in the subgenus *Soja*. The annual species consist of the cultivated type *max* and wild type *soja* Sieb. and Zucc. They have chromosome number 2n = 40 and can be readily intercrossed. The F_1 hybrids from some *G. max* and *G. soja* (two annual species) crosses are semi-sterile due to chromosome translocations. No successful crosses have been reported between *G. max* and the six perennial species of the subgenus *Glycine* (Hadley and Homowitz, 1973). There are more than 100,000 soybean accessions in germplasm bank mainly from USA, China, Japan, Korea, Russia, Australia, Brazil, Germany, Indonesia and some other countries in Asia and Europe (Chowdhury, 2001).

The uses of soybean

Soybean was grown for food and feed in China for many centuries. After Chinese- Japanese War, Japanese imported soybean from China to use as fertilizer (Morse, 1950). Soybean is mainly grown to use the seeds for food in Asia for centuries. Soybean seeds are used in preparing a large variety of fresh, fermented and dried food products. Soybean contains high protein and fiber, low carbohydrates and is nutrient-dense. It is also used as a specific remedy for the proper functioning of the heart, liver, kidneys, stomach and bowels (Probst and Judd, 1973).

Americans began to grow soybean as forage crop in earlier time (Poehlman and Sleper, 1995). In 1904, the famous American chemist, George Washington Carver discovered that soybean was a valuable source of protein and oil. Today, soybean can be found in a wide variety of products, ranging from soybean sprout, tofu, soy milk and soy sauce to plywood, particle board, printing inks, soap, candy products, cosmetics, and antibiotics. More and more researchers are developing new uses of soybean. Recent developments include soy diesel, building materials, candles, road dust suppressants, hand cleaners and soy crayons (Probst and Judd, 1973; Smith and Huyser, 1987).

Soybean production in the World, Thailand and Myanmar

Soybean is native to China, and China led the world soybean production until 1954. In 1992, the United States accounted for 51% of the world's soybean production and soybean became the second largest crop in cash sales and the largest export crop in the United States. In 2006-2007, the world soybean productions shared to U.S. 37.65-32.02%, Brazil 24.52-27.75%, Argentina 19.26-21.38%, China 7.09-6.50% and other countries 22.48-12.35% among 228.4-219.8 MMT of the total. During these years, the United States, Brazil and Argentina involved 29.9-27.9, 25.8-27.7, 7.4-11.5 MMT among 69.6-74.7 MMT of total world soybean export. It was notable that the adoptions of biotech-enhanced soybean in these countries were 89-91%, 56-65.9% and 99.5-95.2% during these periods (Soy Stats, 2007, 2008).

Soybean is also one of the most important grain legume crops in Thailand. It has been widely cultivated as rice-soybean cropping pattern in the upper north of the country since 1930s. The planted area has expanded to the lower part of the northern area and it was later extended to the northeastern region and central plains. In Thailand, soybean is grown in three main seasons, early rainy season (40% of the total planted area), late rainy season (35%) and dry season (25%) (Shrivastava, 1997). In 2005-2006, soybean production area was increased to 152,160-154,423 hectares with the production of 221,000-226,843 MT (Sarobol *et al.*, 2007; Sarobol, 2008).

In Thailand, soybean is considered as a high potential crop for expansion. However, most area of Thailand is too hot for growing soybean except its northern region. One of the main reasons is that soybean production often meets weathering damage cause by the tropical and subtropical climate. The tropical and subtropical weather conditions with high temperature and relative humidity prior to harvest result in rapid decrease in germination and vigor of soybean seeds. It also results in decreasing the quality of seed produced and not conducive to production of desired quality seed to establish acceptable stands in Thailand.

In Myanmar, soybean is one of the potential sources of edible oil. It was grown about 118,000 hectares with the production of 121,000 MT in 2001. It was increased to 157,000 hectares with the production of 204,000 MT in 2006 (DAP, 2007). Normally, it has been cultivated entirely for food purposes. Recently, the concerted efforts have been made soybean processed for edible oil. Due to 2.02 % annually population growth, domestic production of vegetable oil could not keep face with the demand and therefore between 150,000 and 200,000 tons of edible oil have to be imported from abroad (OCDP, 2006).

About 50% of total soybean cultivated area is in Shan State which is located about 1000-1500 meter above sea level. In Shan State, soybean is cultivated during rainy season. It is usually grown as sole, mixed or intercropped with maize, sorghum or sunflower. The rest of soybean is grown in the central plain region (especially, Sagaing, Mandalay and Bago Division) and other hilly region (especially, Kachin

State) as a winter crop, mainly after harvesting rice. In lower Myanmar, soybean is grown on alluvial soils of unbounded area as a winter crop when water is receded (FAO, 2001). The low average yield of soybean in Myanmar is mainly due to the lack of suitable varieties for specific regions, lack of quality seed, susceptibility to disease and insect, lack of crop management practices (lack of irrigation practices, need of management practices before and after harvesting), lack of farm machineries and unavailability of effective rhizobium inoculums (Than, 2008).

Soybean cultivation and weather requirement

Soybeans seed germination occurs at temperature from 5˚C to 40˚C. However, for rapid germination the temperature should be around 30˚C. Generally, soybean begins germination when the soil temperature reaches 10˚C. However, in tropical and subtropical areas (soil temperature above 20˚C) the seedling emerged in 3 to 5 days. The major world soybean producing areas have average mid-season temperature of 23˚C to 25˚C. Soybean vegetative growth is slow or nil at temperature of 10˚C or less and optimum at 30˚C, and then it decreases as the temperature increases above optimum. Soybean growth is the best at 22˚C-27˚C in summer temperatures. A temperature above 40˚C causes adverse effect on growth rate, flower initiation and pod-set. Pod initiation decreases when temperature is below 22˚C and no pods are formed when temperatures is lower than 14˚C. At the seed developing stage, cool and dry conditions during maturation and harvest are optimum. As a general rule, maturation of soybean seeds should occur when average temperature is 22˚C or lower (Franca Neto *et al*., 1994).

The seed moisture content (dry weight basis) required for soybean germination is about 50% (Hicks, 1978). Excess soil moisture severely restricts germination and early growth of soybean. These effects are apparently the result of restricted oxygen movement to the seed and plant roots (Ohmura and Howell, 1960). Small soybean seed may germinate in drier soil than large seed. No emergence of seed is observed at 20% soil moisture. However, for each moisture level where germination occured, the small and medium sized seed give more rapid emergence and greater root development than the large seed (Edward and Hartwig, 1971). Irrigation beginning at flowering is as effective in increasing yield as irrigation throughout the growing season (Matson, 1964). The susceptibility of soybean to moisture stress was probably related to maturity. Yield of soybean is most affected by moisture stress during the pod filling period (Hicks, 1978). Yield of grown soybean with adequate supplies of soil moisture can be affected by atmospheric humidity. A 21% reduction in yield is recorded for soybean grown at day/night relative humidity of 47/46% as compared to 81/84% (Whigham and Minor, 1978).

Soybean seed quality is usually good when produced under favorable environment. However, in many counties, especially in tropical and subtropical countries, the environmental conditions are unfavorable and often detrimental to the production of high quality seed. In many cases, the environments mainly contribute to the rapid deterioration of the seeds (Andrews, 1982).

Soybean seed development

Seed development is concerned with the various processes and stages which occur during fertilization period to that until the seed is fully formed and ready for harvest. Soybean fertilization occurs within 8-10 hours following the pollination. Fertilization initiates cell division to form the embryo, which occurs about 32 hours after pollination. After 6-7 days, localized division at the opposite side of the embryo results in the initiation of the cotyledons. The hypocotyl and epicotyl tissues are also differentiated at the same time (Andrews, 1966). Seed viability of soybean attained about the 12th day after flowering. Seed dry weight increases slowly up to 20 to 30 day after flowering, reaches a maximum at 65-75 day after flowering and remains constant or decreases slightly thereafter. This stage is also called physiological maturity (Delouche, 1974).

During development and maturation, the changes in moisture levels of seeds are also important. Delouche (1974) observed that seed contained 40 to 50 percent moisture at maximum dry weight while Mondragon and Potts (1974) stated a value of

30 percent. About one week after physiological maturity, seed moisture drops to about 15 percent. Developmental processes during seed growth and maturation interact with the production environment to determine the planting quality of a seed population (Miles *et al*., 1988).

Physiological maturity (PM) is defined that the seed reaches its maximum dry weight (Shaw and Loomis, 1950; Harrington, 1972). The PM should also represent maximum viability and vigor of planting seeds (Andrews, 1966; Delouche, 1974; Knittle and Burris, 1976).

Field weathering of soybean seeds

Historically, soybean was produced in the northern regions of the temperate climatic zones of the world, where environmental stress were relatively minimal. However, as the world demand for vegetable oil and protein continued to increase, soybean production spreaded rapidly into the hot and humid production areas, and more recently into the tropical regions (Moore, 1966; Tekrony *et al*., 1987). Since maximum seed quality is acquired by physiological maturity, it is desirable to harvest the seeds as soon as possible thereafter. Practically, however, due to high moisture content (about 55%), the seeds cannot be harvested commercially at this growth stage. They continue to dry down until they reach harvest maturity (about 14% moisture content). They must remain in storage on the plant through a desiccation period till moisture levels are sufficiently low to permit mechanical harvest without causing undue damage to the seed. This period may vary from a few days to over several weeks before the seed reaches a harvestable moisture level. Field conditions are seldom favorable for such storage, especially in the tropics (Delouche, 1971). Deterioration of seed in the field prior to harvest (field weathering) begins when the seed reaches physiological maturity and it continues until the seeds are harvested. Soybean seed quality can be reduced by a wide range of environmental factors during this period (Delouche 1974; Tekrony *et al*., 1980b).

The deterioration of seed vigor as well as viability due to high temperature and high relative humidity during the stages of the post-maturation and pre-harvest period is referred to as field weathering (Tekrony *et al*., 1980a; Bhatia *et al*., 1993). In hot and humid conditions, weathering is the major cause of seed quality loss following physiological maturity (Delouche 1980; Nangju *et al*., 1980).

Fluctuations in temperature and relative humidity determined the degree of soybean seed weathering. High temperature coupled with high moisture exerts severe stresses upon developing soybean seeds. High temperature, humidity and precipitation play a critical role in field weathering (Mondragon and Potts, 1974; Nangju, 1979; Tekrony *et al*., 1980 a; Keigly and Mullen, 1986). Both high temperature and relative humidity in tropical and subtropical environments cause the production of quality soybean seed and the maintenance of seed vigor during storage difficult (Pashal and Ellis, 1978). Delouche (1974) reported that adverse weather conditions during the post-maturation and pre-harvest period caused severe seed quality problems in soybean.

Morse (1950) stated that hot weather during seed maturation often resulted in seed coat wrinkling which reduced germination. Costa *et al*. (1987) evaluated 18 soybean lines in Brazil and found that an alternation of rain and hot weather accelerated deterioration, and high temperature during final stages of seed maturation caused green seeds that were low in quality. The tropical and subtropical weather conditions with high temperature and relative humidity prior to harvest result in rapid decrease in germination and vigor of soybean seeds. Weathering not only lowers seed germination, but also increases susceptibility to mechanical damage (Delouche, 1972; Franca Neto *et al*., 1994; Green *et al*., 1966), and to disease infection (Wilcox *et al*., 1974; Pashal and Ellis, 1978). In addition, tropical and subtropical climates with high temperature and moisture are also favorable for rapid development of disease and insect pests, and obviously lead to a reduction in seed quality. Seeds from such weather-ridden crop lose viability owing to pathogenic infestation and physiological deterioration (Bhatia *et al*., 1993).

The causes of seed deterioration can be pathological, physiological, or mechanical. These causes frequently occur in combination and act synergistically to reduce seed vigor. It appears that pathogens frequently play a major role in seed deterioration from the period of physiological maturity to harvest (Kueneman, 1982). Besides, seed viability decreases even before harvesting when high temperatures and humidity during the maturation period interact with incidence of fungal pathogens to reduce the quality of maturing seed (Green *et al*., 1965; Paschal and Ellis, 1978; Ndimande *et al*., 1981).

Furthermore, seed deterioration under storage condition has been a major constraint to successful soybean production. Under the hot and humid conditions, soybean seed germination is generally low at harvest. Even when germination is high, its viability rapidly decreased during the storage resulted to the poor planting materials by the next sowing season (Popinigis, 1984). Soybean seed normally subjected to the field weathering before harvesting or severely damaged during harvest or if it was not stored quite well which resulted in poor germination at planting (Delouche and Rodda, 1976). Unfavourable condition of high temperature and relative humidity during storage will promote seed deterioration. The effects of the length of storage period on the emergence percentages of the soybean lines were more drastic than the effect of two weeks delay in harvesting on the emergence percentages of these lines when they were planted in the field (Wien and Kueneman, 1981).

Physical, physiological and biochemical changes during field weathering

The tropical and subtropical weather conditions also results in decreasing the physical quality of seed produced such as purple stained seeds (contaminated by fungi), wrinkled seeds, fissures in the seed coat, discolored seed, insect damaged seeds, which are typical symptoms of field deterioration (Moore, 1973; Wolf and Bernard, 1981; Pereira and Andrews, 1985). Seed coat color changes are presumably due to oxidative reactions in the seed coat that are accelerated under conditions of high temperature and relative humidity (Hughes and Sandsted, 1975). Moore (1971) proposed that exposure of mature soybean seed to alternate wetting and drying in the field resulted in embryo destruction and lower quality. Embryonic tissues just beneath the seed coat become damaged during wrinkling, which may result in reduced seed germination and vigor, and a higher percentage of pathogen-infected, abnormal seedlings (Moore, 1972).

Under the conditions of high temperature and relative humidity, oxidative reactions in the seed coat are accelerated (Hughes and Sandsted, 1975). As seeds deteriorate, respiration becomes progressively weaker and ultimately leads to loss of germination. It appears that reductions in the rate of respiration are closely associated with seed deterioration (Woodstock, 1965; Woodstock *et al*., 1984; 1985). Moreover, other potential causes are alterations of membrane systems such as the topoplast, plasmalemma and endoplasmic reticulum which may result in impairment of normal cell function and energy production. Membrane deterioration and loss of permeability occur at an early stage during the seed deterioration (Abu-Shakra and Ching, 1967; Byrd and Delouche, 1971; Delouche and Baskin, 1973). Roos (1986) listed the consequences of membrane damage which included (1) breaks in the structure of plasmalemma and its contraction from the cell wall, (2) fragmented endoplasmic reticulum devoid of polyribosomes, (3) monosomes randomly dispersed in the cytoplasm, (4) absence of dicytosomes, (5) disintegration of mitochondria and plastids, (6) condensation of chromatin and lobed nucleus, (7) coalescence of lipid droplets and (8) lyses of membranes of lysomic structures. One of the earliest theories about seed deterioration was the food reserves were depleted in the seed. This theory is not valid, however, since non-viable seeds usually have ample food reserves (Roos, 1986). Problem associated with the mobilization of these food reserves to the embryonic axis is a theory which is still widely accepted.

There are other potential causes of seed deterioration as quantitative and qualitative alterations of the chemical composition of the seed including storage and functional lipid degradation (oxidation), nucleic acid and protein changes and nucleotide alteration. As seeds deteriorate, their ability to retain cellular constituents decreased which was attributed to cell membrane disruptions and associated with the loss of membrane phospholipids (Powell and Matthews, 1981a; Priestly and Leopold, 1979). It is now commonly believe that lipid peroxidation plays an important role in initiating the seed aging process. Lipid peroxidation can result in not only destruction of the lipid itself, but also damage to cell membranes and other cellular components (Wilson and McDonald, 1986). Lambrecht *et al*. (1996) observed that a soybean mutant lacking lipoxygenase isozymes 2 and 3 were more resistant to changes during adverse storage than soybean with all the isozymes. This indirectly supports the theory that lipid oxidation plays a role in increasing cell membrane permeability (Stewart and Bewley, 1980).

Field weathering resistance in soybean

In tropical conditions, some seed characters for field weathering resistance of soybean are hard seed coat (IITA, 1977; Potts *et al*., 1978; Hartwig and Potts, 1987; Suriyon, 2003), small seed size (Edwards and Hartwig, 1971; Paschal and Ellis, 1978; Nangju, 1979; Dassou and Kueneman, 1984; Horlings *et al*., 1991; Tiwari and Joshi, 1998; Wangkam, 1999), and black seed coat (Starzinger and West, 1982; Dassou and Kueneman, 1984; Kueneman and Costa, 1987; Horlings *et al*., 1994). Among these characteristics, hard seededness has been extensively studied because it was also considered to be related to seed dormancy and seed longevity.

Kueneman (1982) reported that the mechanisms of resistance to deterioration might be associated with the seed coat. The hard seed coat helps to prevent viability loss by limiting the exchange of water and gas between the seed and the environment. The seed coat also has a relevant role in preventing the entry of pathogenic micro-organisms. Dassou and Keuneman (1984) found that the mean emergence scores for 16 black-seeded genotypes after incubator weathering, field weathering and ambient storage were 47, 69 and 82% respectively compared to 9, 52 and 54% for the 19 yellow-seeded genotypes. Studies have shown that viability is maintained longer in smaller than in larger seed (Delouche, 1975; Wien and Kueneman, 1981). The smaller seeded genotypes have higher emergence percentages and less internally seedborne fungi than the larger seeded ones (Paschal and Ellis, 1978). Dassou and Keuneman

(1984) concluded that nearly all large-seeded genotypes were highly susceptible to both weathering and deterioration in storage while small-seeded genotypes having high percentage of hard seeds could resist to field weathering and deterioration in storage. Several studies have suggested that hard seededness can provide protection against seed deterioration (IITA, 1977; Potts *et al*., 1978). Burchett *et al*. (1975) and TeKrony *et al*. (1980a) found that one of the main factors appeared to contribute to the low vigor of soybean seeds was the highly permeable seed coat through which soybeans absorbed moisture easily and thus tended to be more susceptible to weathering in the field as well as to humid tropical environment under open storage conditions.

Genotypic differences in resistance to field weathering have been observed (Green and Pinnel, 1968a; Pashal and Ellis, 1978, Potts *et al*., 1978; Ndimande *et al*., 1981; Korte *et al*., 1983; Kadhem *et al*., 1985). Nangju (1977) and Paschal and Ellis (1978) reported that soybean variety *Improved Pelican* was resistant to purple seed and field weathering. Korte *et al*. (1983) and Kadhem *et al*. (1985) found that soybean varieties *Elf*, *Will* and *Hobbitt* exhibited better visual seed quality than *Nebsoy* and *Amcor*. Ndimande *et al*. (1981) found that two black seeded accessions of Indonesian origin, *TGM685* and *TGM686* were also resistant to field weathering. Lassim (1982) compared the rate of field deterioration of 3 soybean varieties (*Mack*, *Dare* and *Forrest*) and found that the seeds of *Mack* decreased much more rapidly in germination than other varieties and the *Mack* seeds were more adversely affected by delay in harvest and weathering than *Dare* and *Forrest* seeds. It appeared that the seeds of *Mack* cultivar were inherently more susceptible to weathering than the seeds of *Dare* and *Forrest*. Paschal and Ellis (1978) and Costa *et al*. (1987) provided additional evidence that substantial genetic variation existed in different cultivars for seed quality characteristics measured under tropical conditions. Cultivars with small seed size appear to be better adapted to some tropical climates and to be resisted weathering and invasion by pathogens.

In Thailand, Chanprasert *et al.* (2000) studied on the relationship between physical characteristics and quality of seeds of 40 soybean varieties under four different germination methods. The varieties with small seed size, oblong-seed shape, low brightness, low P value and thick seed coat gave higher seed quality than the varieties with large seed size, round shape, high brightness, high P value and thin seed coat. Chanprasert (1990) studied on germinability, vigor and storability of seeds of 18 soybean lines and found that *Chiangmai 60* and other four lines showed the poorest quality while *SJ4*, *SJ5* and other six lines exhibited high seed quality. The rest lines could be judged as medium quality. Besides, Chanprasert *et al*. (2001) examined pore characteristics on seed coat of six soybean varieties. It can be concluded that the difference in seed quality of different soybean varieties may be associated with pore size and pore number per unit area on seed coat. The germination percentages of *Chiangmai 60* and *Sukhothai1* were low under accelerated aging and field emergence tests because of pore characteristics of these varieties. Kaowanant (2003) also found that small seeded soybean lines, *GC10981* and *GC10848* were more resistant to field weathering than *Chiangmai 60*. Soybean cultivar *Kalitur* was found as resistant variety for field weathering (Yupongchay, 2008). This variety has hard seededness and small seed size (Horlings *et al*., 1994).

Genetics of field weathering resistance

In tropical conditions, some seed characters attributed to field weathering resistance of soybean are black seed coat, small seed size, hard seed coat, hard seededness and low permeability of the seed coat. Nagai (1921) showed that a single gene pair controlling black seed coat (*RR*) was completely dominant to brown seed coat (*rr*). He also described a second locus (*C-c*) with a recessive allele that altered black seed coat to imperfect black and brown to buff. Bernard and Weiss (1973) showed that there was a pleiotropic effect of the *T-t* gene pair for pubescence and seed coat color. Thus, tawny pubescence varieties have black or brown pigment in the seed coat whereas grey pubescent varieties have imperfect black or buff pigment. The small seed size is controlled by *Se* (in pure line of PI 196.176) and L_1L_2 (in pure line of PI 85.505) genes. Hoeck *et al*. (2003) reported that seed size is a quantitative trait. Ojo (2006) found that small seed size dominated over large seed size. Kilen and Hartwig (1978) hypothesized that hard seededness was controlled by three or four major genes. They assumed hard seededness was influenced by the maternal plant, as the seed coat is maternal plant tissue. Kaveeta (1982) found that hard seededness in soybean seemed to be heritable with predominantly non-additive gene action, but might be partly controlled by maternal effect. Keim *et al*. (1990) reported that hard seededness in soybean was a quantitative trait that affects the germination rate, viability and quality of stored seeds.

Genotypic differences in resistance to field weathering have been observed (Green and Pinnel, 1968a; Pashal and Ellis, 1978, Potts *et al*., 1978; Ndimande *et al*., 1981). Green and Pinnel (1968a, 1968b) and Kueneman (1982) evaluated the inheritance of resistance to field weathering by crossing the resistant cultivars with the susceptible cultivars; they also assumed maternal control of the resistance. Broad sense and narrow sense heritability estimates based on field emergence and laboratory germination were very low. Their results also showed low narrow sense heritability for wrinkled seed coats, shriveled cotyledons, green cotyledons and overall visual rating. However, genetic differences in seed deterioration appeared to be small in comparison with the effect of environmental stress (Tekrony *et al.,* 1980b). Some cultivars of soybean appeared to be inherently more susceptible to field deterioration than others (Lassim, 1982). Unander *et al*. (1983) detected a significant genotype and environment interaction following selection of 20 cultivars for improved seed germination ability. They found that genetic variability for seed quality existed but degree of potential improvement was small in comparison with the main effect of environment. Like some other environmental stress resistance in plants, the field weathering resistance of soybean might be controlled by polygene (QTLs). It was reported that field weathering resistance of soybean appeared to be a quantitative trait (Changrong *et al*., 2006; Dechkrong, 2006) and it hinted that field weathering resistance of soybean was controlled by polygene (Dechkrong, 2006; Changrong *et al*., 2007b).

Breeding for field weathering resistance

The basic breeding methods in soybean are pedigree, bulk-population and various modifications of pure line method. However, these breeding methods have been modified. Modified pedigree method of selection (single-seed descent) was outlined by Brim (1966). This method was based on the finding that additive genetic variance comprises the large portion of total genetic variance for most characters in soybeans. In Kasetsart University, Phan *et al*. (2006) selected six advanced lines of soybean from two single crosses by pedigree method. One modification of the pure line method that has been used extensively is the backcross. Backcrossing has been used primarily for the transfer of resistance to diseases and nematodes to adapted varieties. Bulk-population method has not been used extensively in soybean improvement at the earlier period (Brim, 1973). But, at present, this method is widely used at the National Soybean Research Center of Brazilian Agricultural Research Enterprise (CNPSo-EMBRAPA) because of its simplicity and the method can eliminate some undesirable or unadapted segregates from the populations. Besides, the single-seed descent method is currently the most widely used method of increasing homozygosity in soybean at this center (Ferraz de Toledo *et al*., 1994). Breeding objectives have also been changed from the initial primary emphasis on yield to include other traits that are believed necessary for wider adaptation to expanding production. Some cultivars for disease and shattering resistance and suitability to mechanical harvesting have been mainly developed. Improvements in physical and chemical attributes of the seed have also been attained (Brim, 1973). To improve seed quality in subtropical and tropical soybean production areas, resistances to unfavorable conditions should incorporate in breeding programs (Andrews, 1982).

Soybean breeders in the tropics have made significant efforts towards developing adapted cultivars with genetically improved seed quality. This task has received greatest emphasis at the International Institute of Tropical Agriculture (IITA) in Nigeria and at the National Soybean Research Center of the Brazilian Agricultural Research Enterprise. At the IITA, several soybean lines from Southeast Asia with small and black seeds were found to have good seed quality. Eight months after ambient storage reduced the emergence of the soybean cultivar *Bossier* to nearly zero, whereas the selected lines maintained at least 50% emergence (Wien and Kueneman, 1981). Researches in Brazil have confirmed the possibility of selecting for improved seed quality among soybean lines, and several sources of high seed quality have been identified (Ferraz de Toledo *et al*., 1994). *Doko* released in Brazil in 1980 was an example of a tropically adapted cultivar with good seed quality. Fungicide-treated seeds of this cultivar could overcome severe accelerated aging condition (41˚C for 96 hours) without any decrease in germination (Franca Neto *et al*., 1984).

Some breeding programs have recognized the importance of hard seededness and have introgressed this trait into adapted cultivars (Kilen and Hartwig, 1978). In recent years, a growing interest in the genetic incorporation of specific seed coat trait associated with imbibition control in soybean genotype breeding occurred with the aim of increasing seed storage potential and reducing field deterioration (Potts *et al*., 1978). However, hard seed coat is also not desired in commercial soybean varieties because it causes un-uniform germination and emergence. Disadvantages include an increased number of volunteer plants in later crops, a reduced rate of stand establishment and the need to scarify seed lots having high levels of hard seededness (Potts *et al*., 1978). Small seed size and black seed coat are also not desired in the market even they are not influence the yield (Hartwig and Edwards, 1970). Although soybean cultivars with high percentages of impermeable seed coats are less prone to weathering, however, there are some undesirable attributes that may restrict its use. Expression of this character is influenced by several environmental factors. Water stress, seed size and field environment have combination effects on seed coat permeability (Hartwig and Potts, 1987; Hill *et al*., 1986a; 1986b; Minor and Paschal, 1982). There are also some restrictions on the physical characteristics of the seed. For example, yellow seed coat and cotyledon color are considered essential. Colorless hilum is also desirable since it linked to unwanted mottled seed coat color. The development of more efficient breeding procedure is dependent upon the types of gene action of the characters themselves and their linked characters (Brim, 1973). Special carefulness is needed to use these characteristics in breeding programs.

MATERIALS AND METHODS

Materials and equipments

1. Plant materials

One susceptible field weathering variety, *Chiangmai 60* (Kaowanant, 2003) and two field weathering resistance varieties, *GC 10848* (Kaowanant, 2003) and *Kalitur* (Yupongchay, 2008) and their progenies were used in this study.

Chiangmai 60 (CM60) was released by the Department of Agriculture, Ministry of Agriculture and Co-Operatives in 1987. It gave average yield of 2,460 kg/ha, plant height of 87 cm, growing period from 90-95 days and one hundred-seed weight of 18 g. Seed composition contains 20.2% oil and 43.8% protein. It exhibits indeterminate growth habit. It is widely grown and a high yielding variety in Thailand. *GC 10848* has determinate growth habit and it is a low yielding variety. *Kalitor* shows indeterminate growth habit and it gives low yield (Srisombun, 2000).

2. Equipments

2.1 Equipments for hybridization : forceps, scissors and tags, etc.

2.2 Equipments for soybean planting : pots, soil and compost, fertilizers, insecticides and fungicides.

2.3 Equipments for field weathering test : wire mesh trays, plastic boxes, beakers, paper towers, razor blade, incubator, electrical conductivity meter (Cyberscan PC 510), hot air oven and balance.

Methods

1. Planting the parental varieties

Chiangmai 60, GC 10848 and *Kalitur* were grown in the greenhouse at the Department of Agronomy, Kasetsart University as susceptible and resistant parents. These parental plants were managed with fertilizers, insecticides and fungicides as necessary. The performance of each parental plant was determined.

2. Crossing for production of F_1 hybrid seeds

Emasculation and pollination were done between female susceptible parent (*CM60*) and male resistance parents (*GC10848* and *Kalitur*) for two cross combinations following the method described by Poehlman and Sleper (1995). The F_1 hybrid seeds were produced on the female parental plants.

3. Production of F_2 seeds

The F_1 hybrid seeds and their parents were planted in the greenhouse again. The F_1 plants were identified for real hybrids using hypocotyl color and flower color as morphological markers which were described by Bernard and Weiss (1973). *CM60* had green hypocotyl and white flower whereas *GC10848* and *Kalitur* had purple hypocotyl and purple flower. Therefore, F_1 hybrid plants with purple hypocotyl and purple flower were selected as real F_1 hybrid plants. The F_2 seeds are produced on the F_1 plants.

4. Field test

Parental varieties, F_1 hybrids and F_2 progenies were grown in the experimental field during dry season 2008 at the National Corn and Sorghum Research Center, Pakchong District, Nakhon Rachasima Province. The dimension of individual plot size was 3 x 3 square meters with six rows including two rows of parental varieties and one row of F_1 hybrids or four rows of F_2 progenies for each cross. The spacing between rows was 50 cm and between hills was 25 cm. Water, fertilizers, insecticides and fungicides were applied as necessary. At physiological maturity, the yellow pods were harvested from each plant of parental varieties, F_1 hybrids and F_2 progenies for field weathering test. At this stage, about 95% of the pods were yellow but they had not turned brown yet (Dassou and Kueneman, 1984). This stage was approximately R7.5 as described by Horling *et al*. (1994).

5. Field weathering test

The yellow pods harvested from each plant of parental varieties, F_1 hybrids and F_2 progenies were air dried to approximately 12% moisture content and hand-threshed. The seeds obtained were subjected to the following field weathering tests.

5.1 Accelerated aging test (AA test)

Twenty five seeds from each plant of parental varieties, F_1 hybrids and F_2 progenies were put on a wire-mesh tray. The trays were sealed in a plastic box with 1 cm high of water under the trays to make sure a high relative humidity (90-100%) during incubation. The boxes were then incubated at 41ºC for 3 days (AOSA, 1983). The treated 25 seeds were germinated between wet papers at 25ºC for 5 days. The normal seedling, abnormal seedlings, fresh un-germinated seeds, hard seeds and dead seeds were counted. Germination percentage was calculated according to ISTA (1985).

5.2 Electrical conductivity test (EC test)

Twenty five seeds from each plant of parental varieties, F_1 hybrids and F_2 progenies were weighed and soaked in 75 ml of distilled water in 200 ml beaker with two replications. Control treatment is done by adding only 75 ml distilled water into 200 ml beaker. The beakers were covered with aluminum foil and incubated at 20˚C for 24 hours (AOSA, 1983). Then the electrical conductivity (EC) of mixture (leakage from seeds and water) and distilled water (control treatment) were measured by Cyberscan PC 510 digital meter. The EC value the leakage from seeds was determined by subtracting the EC of distilled water from the EC of mixture (leakage from seeds and water) and recorded in microSeimen (μS) per cm per gram of seed.

5.3 Measurement of seed coat percentage

Ten seeds from each plant of parental varieties, F_1 hybrids and F_2 progenies were soaked in distilled water and incubated at 5 ºC for 15-16 hours. Seed coat was separated from seed using razor blade. The seed (without seed coat) and seed coat were dried in hot air oven at 105 ºC for 24 hours. After drying, the seed (without seed coat) and seed coat were weighed and the seed coat percentage was calculated (Kuo, 1989).

5.4 Measurement of seed weight

One hundred dried seeds from each plant of parental varieties, F_1 hybrids and F_2 progenies were weighed by digital balance.

6. Determination of agro-morphological characters

Some morphological and agronomic characters of parental plants, F_1 hybrids and F_2 progenies were determined following the descriptions given by Field Crops Research Institute (1997). The characters studied were listed below.

6.1 Hypocotyl color was classified into two groups according to the color of stem at the portion of ground to cotyledon (about a week after emergence).

1. Purple
2. Green

6.2 Flower color was classified into two groups according to the color of petal at R_2 stage.

1. White
2. Purple

6.3 Seed coat color was divided into six groups.

1. Yellow
2. Yellowish brown
3. Green
4. Reddish brown
5. Imperfect black
6. Black

6.4 Stem termination type was classified into three groups.

1. Determinate
2. Semi-determinate
3. Indeterminate

6.5 Plant height was measured from the base of main stem to the terminal node (cm).

6.6 Number of days to 50% flowering was counted from emergence to 50% of plants having first flowering.

6.7 Number of days to maturity was counted from emergence to 95-100% of pods turning yellow (physiological maturity).

7. Data analysis

Field weathering resistance of soybean seeds from each plant of parental varieties, F_1 hybrids and F_2 progenies of the two crosses were evaluated by germination percentage after accelerated aging test, electrical conductivity value and seed coat percentage and seed weight. Mean, standard error and the frequency distribution of the parental varieties, F_1 hybrids and F_2 progenies for these four parameters were calculated. Mid-parent values and dominance percentages of the two crosses for the four parameters were also calculated. Some morpho-agronomic characters were recorded and analyzed for inheritance by Chi-square test using the formula of Falconer (1981). Dominance percentages and heritability of some seed characteristics of two soybean crosses were calculated using the formulas of Mather and Jink (1982; 1971). The formulas were shown below.

$$\chi 2 = \sum \left[\frac{(O_i - E_i)^2}{E_i} \right]$$

Where , $\chi 2$ = chi-square value

O_i = number of observed individual of the i^{th} group

E_i = number of expected individual of the i^{th} group

$$\%\text{dominance} = \frac{F_1 - MP}{MP} \times 100\ \%$$

Where , F_1 = phenotypic expression of F_1

$MP = \frac{P_1 + P_2}{2}$ = mid-parent value

$$h^2_{BS} = \frac{\delta^2_{F_2} - \dfrac{\delta^2_{P_1} + \delta^2_{P_2} + \delta^2_{F_1}}{3}}{\delta^2_{F_2}}$$

Where , h^2_{BS} = broad-sense heritability

$\delta^2_{P_1}, \delta^2_{P_2}, \delta^2_{F_1}$ = phynotypic variance of P_1, P_2 plants and F_1 progeny, respectively

$\delta^2_{F_2}$ = phynotypic variance of F_2 progenies

Note : -Non-genetic or environmental variances are assumed in the P_1, P_2 and F_1progenies.

-A single gene model is assumed.

-No epistasis or linkage presented.

RESULTS AND DISCUSSION

Inheritance of field weathering resistance

1. Field weathering resistance manifested by germination percentage

In accelerated aging (AA) test, germination after aging closely related to field emergence under adverse conditions (Delouche and Baskin, 1973). The two environmental variables, high temperature and high humidity in AA test cause rapid deterioration of the exposed seeds. High vigor seed lots will withstand these extreme stress conditions and deteriorate at a slower rate than low vigor seed ones (AOSA, 1983). The AA test is one of the most frequently used for seed vigor evaluation. The seed lots with high germination percentage had high seed vigor whereas those with low germination percentage gave low seed vigor (Ferguson *et al.,* 1990). Dassou and Kueneman (1984) reported that soybean genotypes with high percentage of germination following weathering treatment were resistant to field weathering. Egli and TeKrony (1995) indicated that soybean seed lots with higher germination rate after AA test manifested high probability of producing adequate seedling emergence under severe environmental conditions. Furthermore, Marwanto (2003) reported that germination after weathering stress significantly correlated with seed quality during weathering. Phan *et al*. (2006) evaluated that the lines with higher percentages of seed germination following AA test were resistant to field weathering.

In this study, Table 1 showed the range and mean of parental varieties (susceptible variety *CM 60* and resistant varieties *GC 10848* and *Kalitur*), F_1 hybrids and F_2 progenies of the two soybean crosses for germination percentages after AA test. Mid-parent values and dominance percentages were also expressed. The mean germination percentages of *CM 60*, *GC 10848* and *Kalitur* were 43.20, 88.80 and 86.67%, respectively. It indicated that resistant parental varieties gave much higher germination percentages than the susceptible one. For the cross *CM 60* x *GC 10848*, mean germination percentages of F_1 hybrids and mid-parent value were 70 and 66%

whereas the germination percentages of F_2 progenies ranged from 33 to100% with the mean value of 68.13%. For the cross *CM 60* x *Kalitur*, mean germination percentages of F_1 hybrids and mid-parent value were 69.23 and 64.93% whereas the germination percentages of F_2 progenies varied from 32 to 100% with mean value of 67.28%.

Table 1 Range and mean (± standard error) for germination percentages after AA test of parental varieties, F_1 hybrids and F_2 progenies in the two soybean crosses.

Population	CM60 x GC10848		CM60 x Kalitur	
	Range	Mean± S.E	Range	Mean±S.E
P_1	24-60	43.20±1.78	24-60	43.2±1.78
P_2	82-100	88.80±1.03	82-94	86.67±0.65
F_1	65-75	70.00±1.29	57-81	69.23±1.26
F_2	33-100	68.13±1.02	32-100	67.28±0.84
Mid-parent	66.00		64.93	
Dominance (%)	6.06		6.62	

Figure 1a and 1b manifested the frequency distribution of the parental varieties, F_1 hybrids and F_2 progenies for germination percentages in the crosses *CM60* x *GC10848* and *CM60* x *Kalitur*. The frequency curves of germination percentage of the F_2 progenies of both crosses continuously distributed and showed normal distribution. Therefore, field weathering resistance identified by germination percentages in soybean was controlled by polygene. Furthermore, Table 1 also showed that the mean germination percentages of F_1 hybrids of both crosses were intermediate between those of parental varieties and higher than the mid-parent value. The dominance percentages of both crosses were 6.06 and 6.62% which revealed partial dominance of resistance to field weathering. The result was in agreement with the findings of Dechkrong (2006) and Changrong *et al*. (2006, 2007b) who found that field weathering resistance of soybean appeared to be a quantitative trait controlled by polygene. Unander *et al*. (1983) expressed that like some other environmental stress resistance in plants, field weathering resistance of soybean may also be controlled by polygene.

(a) (b)

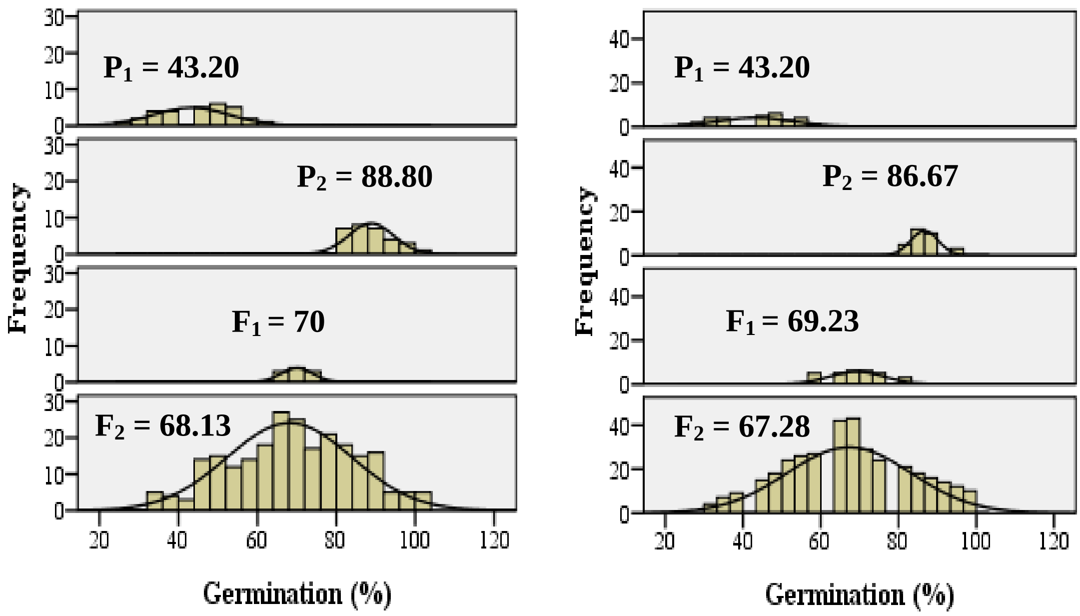

Figure 1 Frequency distribution of parental varieties, F_1 hybrids and F_2 progenies of the two soybean crosses *CM60* x *GC10848* (a) and *CM60* x *Kalitur* (b) for germination percentage after AA test.

2. Field weathering resistance identified by electrical conductivity value

The electrical conductivity (EC) of seed leachate has been satisfactorily used to determine the vigor of soybean seed (AOSA, 1983). Hampton and TeKrony (1995) reported that membrane structure and cell leachate were usually associated with seed vigor. The highly vigorous seeds could re-establish their membrane integrity at a faster rate with less leachate (lower EC value) than the low vigorous ones. Furthermore, Chanprasert *et al.* (1996) found that an EC value of seed leachate was correlated with seed quality including seed vigor during field deterioration (weathering). Phan *et al.* (2006) evaluated that soybean lines with low EC values of seed leachate (higher seed vigor) were resistant to field weathering. Dechkrong (2006) expressed that the F_2 progenies having low EC values were resistance while those giving high EC values were susceptibility to field weathering. Win *et al.* (2009)

reported that soybean varieties/lines with lower EC values of seed leachate tended to be more resistant to field weathering.

In current study, Table 2 indicated the range and mean of parental varieties (susceptible variety *CM 60* and resistant varieties *GC 10848* and *Kalitur*), F_1 hybrids and F_2 progenies of the two soybean crosses for EC value of seed leachate. Mid-parent values and dominance percentages were also presented. The mean EC value of *CM 60*, *GC 10848* and *Kalitur* were 131.40, 78.05 and 85.20 µS/cm/g seed, respectively. It pointed that resistant parental varieties gave much lower EC value than the susceptible one. For the cross *CM 60* x *GC 10848*, mean EC value of F_1 hybrids and mid-parent values were 113.99 and 104.72 µS/cm/g seed whereas the EC value of F_2 progenies ranged from 70.82 to 146.49 µS/cm/g seed with the mean value of 109.28 µS/cm/g seed. For the cross *CM 60* x *Kalitur*, mean EC value of F_1 hybrids and mid-parent value were 119.04 and 108.30 µS/cm/g seed whereas the EC values of F_2 progenies varied from 62.33 to 150.09 µS/cm/g seed with the mean value of 113.65 µS/cm/g seed.

Table 2 Range and mean (±standard error) for EC values of seed leachate (µS/cm/g seed) of parental varieties, F_1 hybrids and F_2 progenies in the two soybean crosses.

Population	CM60 x GC10848		CM60 x Kalitur	
	Range	Mean± S.E	Range	Mean±S.E
P_1	123.00-140.00	131.40±0.92	123.00-140.00	131.40±0.92
P_2	64.09- 91.09	78.05±1.34	74.00- 94.00	85.20±1.21
F_1	105.49-123.49	113.99±2.20	105.31-130.31	119.04±1.39
F_2	70.82-146.49	109.28±0.77	62.33-150.09	113.65±0.70
Mid-parent	104.72		108.30	
Dominance (%)	8.85		9.92	

Figure 2a and 2b showed the frequency distribution of the parental varieties, F_1 hybrids and F_2 progenies for EC values of seed leachate in the crosses *CM60* x *GC10848* and *CM60* x *Kalitur*. The frequency curves of EC value of the F_2 progenies of both crosses continuously distributed and showed normal distribution. Therefore, field weathering resistance evaluated by EC value in soybean was controlled by polygene. Table 2 demonstrated that in the cross *CM 60* x *Kalitur*, the lowest EC value of some F_2 progenies (62.33 µS/cm/g seed) were lower than that of resistant parent *Kalitur* (74 µS/cm/g seed) and the highest EC values of some F_2 progenies (150.09 µS/cm/g seed) were higher than that of susceptible parent *CM 60* (140 µS/cm/g seed). It revealed that the character in this cross had transgressive segregation. This finding was consistent with the report of Dechkrong (2006) that field weathering resistance expressed by EC value of seed leachate was monitored by polygene with transgressive segregation in F_2 progenies. Moreover, table 2 also showed that the mean EC values of F_1 hybrids of both crosses were intermediate between those of parental varieties and higher than the mid-parent values. The dominance percentages of the both crosses were 8.85 and 9.92% which implied partial dominance of susceptibility to field weathering. The partial dominance of susceptibility to field weathering might be affected by maternal variety *CM60* which was supported by the finding of Kilen and Hartwig (1978) who studied the heritability of impermeable seed coat associated with EC value and assumed that the trait was controlled by maternal tissue.

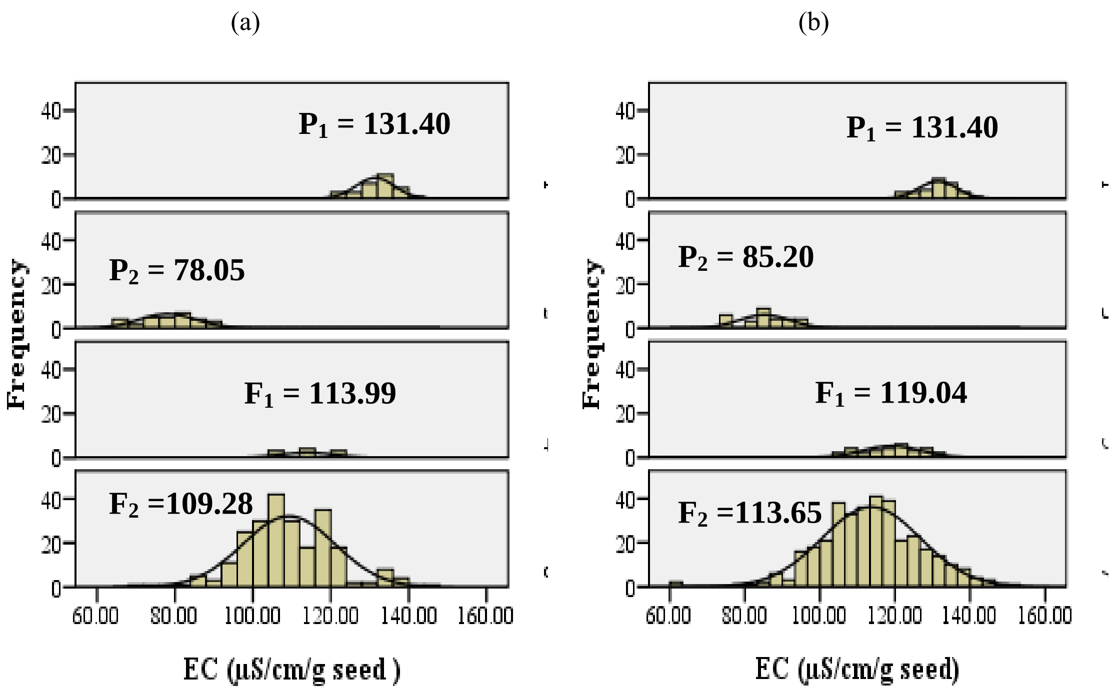

Figure 2 Frequency distribution of parental varieties, F_1 hybrids and F_2 progenies of the two soybean crosses *CM60* x *GC10848* (a) and *CM60* x *Kalitur* (b) for EC values of seed leachate.

3. Field weathering resistance revealed by seed coat percentage

Kuo (1989) reported that soybean seed possessing higher specific weight of testa showed lower membrane permeability. Consequently, high seed vigor of soybean lines might be resulted from the delayed permeability of the seed coat when the seeds exposed to field weathering. This finding opens up the possibility of breeding soybean cultivars resistant to field weathering by improvement seed which produces high proportion of seed coat with delayed permeability Chanprasert *et al.* (1996) found that seed coat percentage and seed weight were correlated with seed quality during field deterioration (weathering). Phan *et al*. (2006) identified that the field weathering resistant soybean lines having high seed germination and vigor exhibited higher percentage of seed coat than the susceptible ones. Dechkrong (2006) reported that F_2 progenies having high seed coat percentages tended to be more resistant to field weathering than the ones with low seed coat percentages. Win *et al.* (2009) also stated that soybean genotypes with low seed weight tended to have high seed coat percentage which caused greater resistance to field weathering.

In present study, Table 3 showed the range and mean of parental varieties (susceptible variety *CM 60* and resistant varieties *GC 10848* and *Kalitur*), F_1 hybrids, F_2 progenies of the two soybean crosses for seed coat percentages. Mid-parent values and dominance percentages were also mentioned. The mean seed coat percentages of *CM 60*, *GC 10848* and *Kalitur* were 5.99, 7.60 and 8.34%, respectively. It pointed that resistant parental varieties gave higher seed coat percentages than the susceptible one. For the cross *CM 60* x *GC 10848,* mean seed coat percentage of F_1 hybrids and mid-parent value were 7.20 and 6.79 % whereas the seed coat percentages of F_2 progenies ranged from 3.70 to 9.30% with the mean value of 6.92%. For the cross *CM 60* x *Kalitur*, mean seed coat percentage of F_1 hybrids and mid-parent value were 7.88% and 7.16 while seed coat percentages of F_2 progenies varied from 4.20 to 10.10% with the mean value of 7.47%.

Table 3 Range and mean (±standard error) for seed coat percentages of parental varieties, F_1 hybrids and F_2 progenies in the two soybean crosses.

Population	CM60 x GC10848		CM60 x Kalitur	
	Range	Mean± S.E	Range	Mean±S.E
P_1	5.20-6.90	5.99±0.09	5.20-6.90	5.99±0.09
P_2	6.90-8.20	7.60±0.06	7.40-9.50	8.34±0.12
F_1	6.60-7.80	7.20±0.11	7.40-8.50	7.88±0.06
F_2	3.70-9.30	6.92±0.07	4.20-10.10	7.47±0.05
Mid-parent	6.79		7.16	
Dominance (%)	6.04		10.05	

Figure 3a and 3b indicated the frequency distribution of the parental varieties, F_1 hybrids and F_2 progenies for seed coat percentages in the crosses *CM60* x *GC10848* and *CM60* x *Kalitur*. The frequency curves of seed coat percentage of the

F_2 progenies of both crosses continuously distributed and showed normal distribution. Therefore, field weathering resistance manifested by seed coat percentage in soybean was controlled by polygene. Furthermore, Table 3 also showed that the mean seed coat percentages of F_1 hybrids of both crosses were intermediate between those of parental varieties and higher than the mid-parent value. The dominance percentages of both crosses were 6.04 and 10.05% which revealed partial dominance of resistance to field weathering. Moreover, in both crosses, the lowest seed coat percentages of some F_2 progenies (3.70 and 4.20%) were lower than that of the susceptible parent *CM 60* (5.20%) and the highest seed coat percentages of some F_2 progenies (9.30 and 10.10%) were higher than those of the resistant parents *GC 10848* (8.20%) and *Kalitur* (9.50%). It implied that the character had transgressive segregation. The result was in agreement with the study of Dechkrong (2006) who found that field weathering resistance of soybean identified by seed coat percentage was controlled by polygene with transgressive segregation of F_2 progenies.

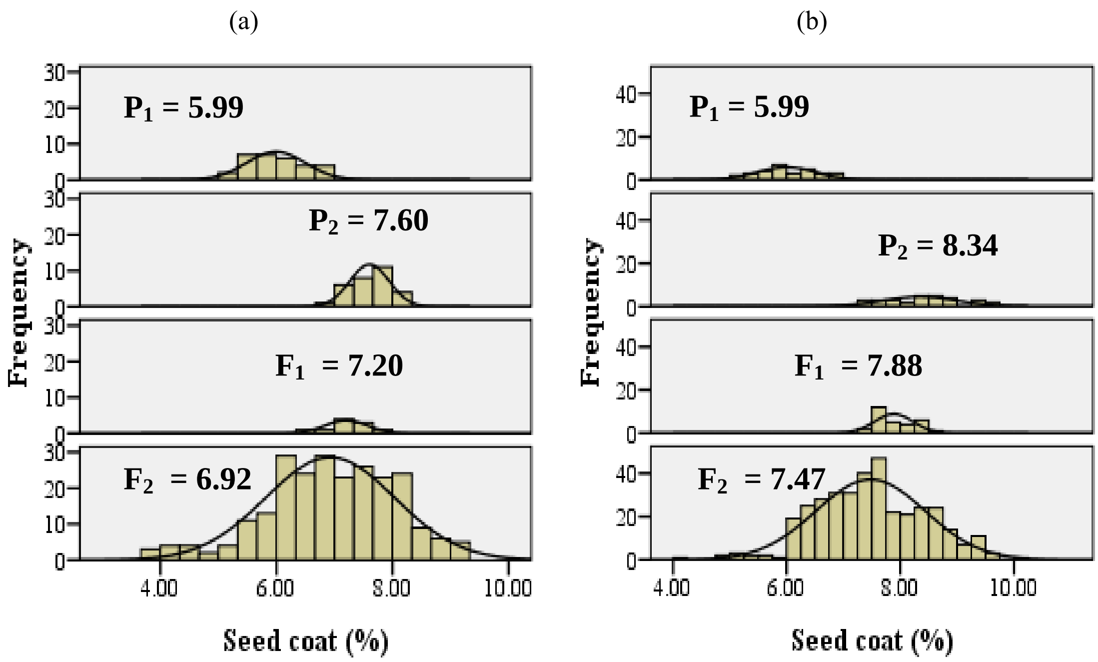

Figure 3 Frequency distribution of parental varieties, F_1 and F_2 progenies of the two crosses of soybean *CM60* x *GC10848* (a) and *CM60* x *Kalitur* (b) for seed coat percentage.

4. Field weathering resistance expressed by seed weight

Cultivars with small seed size appeared to be more adaptable to some tropical climates. Seed size was negatively correlated with field emergence and positively correlated with the incidence of fungi. The smaller seeded genotypes had higher emergence percentages and less internally seed borne fungi (Paschal and Ellis, 1978). Ferraz de Toledo *et al*. (1994) manifested that soybean lines with small seed seemed to retain their quality better than those with large seed. Dassou and Keuneman (1984) concluded that small-seeded genotypes having high percentages of hard seeds could be resistant to field weathering and deterioration in storage whereas nearly all large-seeded genotypes were highly susceptible to both weathering and deterioration in storage.

In present study, Table 4 showed the range and mean of parental varieties (susceptible variety *CM 60* and resistant varieties *GC 10848* and *Kalitur*), F_1hybrids, F_2 progenies of the two soybean crosses for seed weight. Mid-parent values and dominance percentages were also presented. The mean seed weight of *CM 60*, *GC 10848* and *Kalitur* were 16.96, 12.61 and 10.29 g/100 seeds respectively. It showed that resistant parental varieties gave lower seed weight than the susceptible one. For the cross *CM 60* x *GC 10848,* mean seed weight of F_1 hybrids and mid-parent value were 13.73 and 14.78 g/100 seeds while the seed weight of F_2 progenies ranged from 9.83 to 19.95 g/100 seeds with the mean value of 14.24 g/100 seeds. For the cross *CM 60* x *Kalitur*, mean seed weight of F_1 hybrids and mid-parent value were 11.95 and 13.62 g/100 seeds whereas seed weight of F_2 progenies varied from 7.63 to 16.95 g/100 seeds with the mean value of 12.82 g/100 seeds.

Table 4 Range and mean (±standard error) for seed weight (g/100 seeds) of parental varieties, F_1 hybrids and F_2 progenies in the two soybean crosses.

Population	CM60 x GC10848		CM60 x Kalitur	
	Range	Mean± S.E	Range	Mean±S.E
P_1	14.80-18.50	16.96±0.21	14.80-18.50	16.96±0.21
P_2	11.60-13.40	12.61±0.11	9.70-10.80	10.29±0.08
F_1	13.40-14.20	13.73±0.10	11.60-12.30	11.95±0.04
F_2	9.83-19.95	14.24±0.12	7.63-16.95	12.82±0.07
Mid-parent	14.78		13.62	
Dominance (%)	7.10		12.26	

Figure 4a and 4b indicated the frequency distribution of the parental varieties, F_1 hybrids and F_2 progenies for seed weight in the crosses *CM60* x *GC10848* and *CM60* x *Kalitur*. The frequency curves of seed weight of the F_2 progenies of both crosses continuously distributed and showed normal distribution. Therefore, field weathering resistance manifested by seed weight in soybean was controlled by polygene. Furthermore, Table 4 also showed that the mean seed weight of F_1 hybrids were intermediate between those of parental varieties and lower than the mid-parent value. The dominance percentages of both crosses were 7.10 and 12.26% which revealed partial dominance of resistance to field weathering. The result was in consistent with the report of Hoeck *et al.* (2003) who found that seed size of soybean was a quantitative trait and that of Ojo (2006) who recovered that small seed size of soybean dominated over the lager one. Moreover, in both crosses, the lowest seed weight of some F_2 progenies (9.83 and 7.63 g/100seeds) were lower than that of the resistant parents *GC 10848* (11.60) and *Kalitur* (9.70 g/100seeds) and the highest seed weight of some F_2 progenies (19.95) were higher than those of the susceptible parent *CM 60* (16.96 g/100seeds). It implied that this character had transgressive segregation.

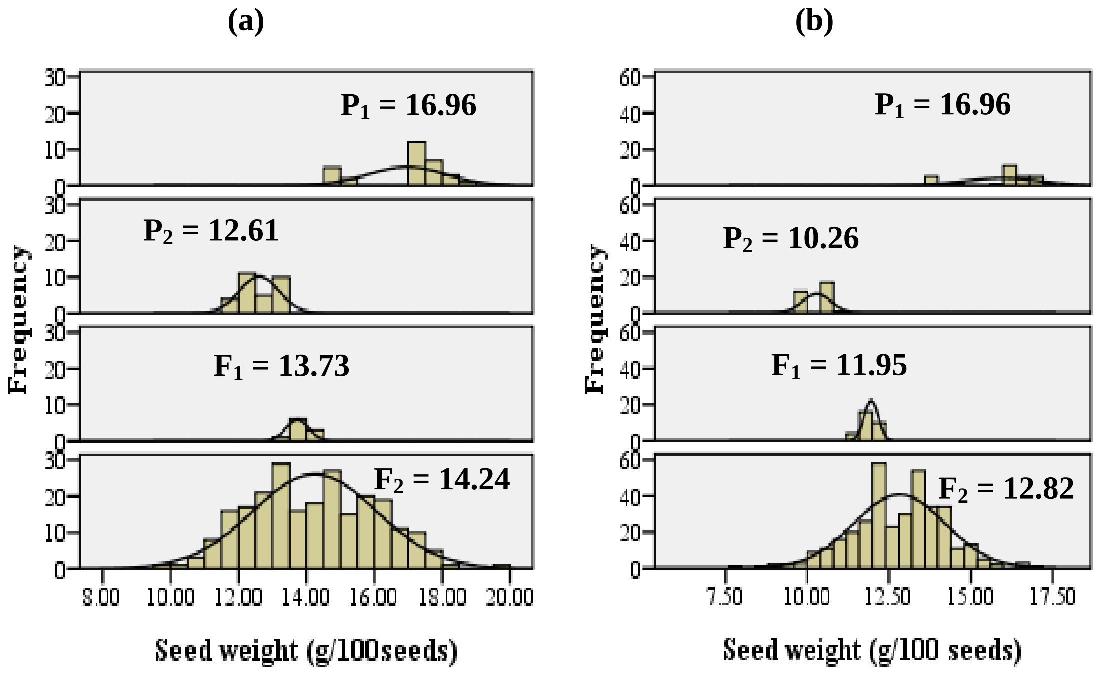

Figure 4 Frequency distribution of parental varieties, F_1 and F_2 progenies of the two crosses of soybean *CM60* x *GC10848* (a) and *CM60* x *Kalitur* (b) for seed weight.

Relationship between some seed characteristics attributed to field weathering resistance

Correlations between some seed characteristics attributed to field weathering resistance of the F_2 progenies of two soybean crosses were analyzed and shown in Table 5, 6.

Seed germination percentage exhibited highly negative correlation with EC value of seed leachate (r = -0.775**, -0.763**), highly positive correlation with seed coat percentage (r = 0.742**, 0.872**) and highly negative correlation with seed weight (r = -0.739**, -0.896**) in both crosses (Table 5 and 6). These correlations revealed that the seeds which had high germination percentage, low EC value of seed leachate, high seed coat percentage and low seed weight were attributed to field weathering resistance of soybean. This observation was in agreement with the finding demonstrated by Win *et al*. (2009) that field weathering resistance of soybean was positively correlated with germination percentage, viability percentage and seed coat percentage but negatively correlated with EC value of seed leachate and seed weight.

The EC value showed highly negative correlation with seed coat percentage (r = -0.822**, -0.682**) and highly positive correlation with seed weight (r = 0.851**, 0.689**) whereas seed coat percentage had highly negative correlation with seed weight (r = -0.912**, -0.807**) in both crosses (Table 5 and 6). These correlations confirmed that the seeds which had low EC value of seed leachate, high seed coat percentage and low seed weight were contributed to field weathering resistance of soybean. The finding was in accordance with the report of Phan *et al*. (2006) who found the negative correlation between EC value seed leachate and seed coat percentage in soybean lines resistant to field weathering. Moreover, Win *et al*. (2009) reported that the positive correlation were found between field weathering resistance and seed coat percentage whereas the negative correlation were recovered between field weathering resistance and EC value of seed leachate and seed weight. Chanprasert *et al*. (1996) also observed that EC value of seed leachate, seed coat percentage and seed weight were correlated with seed quality during field deterioration. Dassou and Kueneman (1984) and Nangju (1977) reported that small seeded genotypes were more resistant to seed weathering than the large seeded ones.

Table 5 The correlations between seed characteristics of F_2 progenies from the cross of *CM 60* x *GC10848*.

	Germination % (AA test)	EC value	Seed coat %
EC value	-0.775**	-	-
Seed coat %	0.742**	-0.822**	-
Seed weight	-0.739**	0.851**	-0.912**

Table 6 The correlations between seed characteristics of F_2 progenies from the cross of *CM 60* x *Kalitur*.

	Germination % (AA test)	EC value	Seed coat %
EC value	-0.763**	-	-
Seed coat %	0.872**	-0.682**	-
Seed weight	-0.896**	0.689**	-0.807**

Linear correlations between some seed characteristics attributed to field weathering resistance of the F_2 progenies of two soybean crosses were analyzed and presented in Figure 5, 6.

The germination percentage after AA test had highly negative linear correlation with EC value of seed leachate, highly positive linear correlation with seed coat percentage and highly negative linear correlation with seed weight in both soybean crosses (Figure 5). The coefficient of determination (R^2) between these seed characteristics were 0.599, 0.551 and 0.546 in the cross *CM60* x *GC10848* (Figure 5a, 5c and 5e) whereas the values were 0.581, 0.763 and 0.803 in the cross *CM60* x *Kalitur* (Figure 5b, 5d and 5f), respectively. Therefore, the coefficient of determination between germination percentage (AA) and seed coat percentage and germination percentage (AA) and seed weight in the cross *CM60* x *Kalitur* were more than those in the cross *CM60* x *GC10848*.

The EC value of seed leachate exhibited highly negative linear correlation with seed coat percentage and highly positive linear correlation with seed weight in both soybean crosses. The coefficient of determination (R^2) between these seed characteristics were 0.676 and 0.723 in the cross *CM60* x *GC10848* (Figure 6a and 6c) while the values were 0.467 and 0.474 in the crosses *CM60* x *Kalitur* (Figure 6b and 6d), respectively. Therefore, the coefficient of determination between EC value of seed leachate and seed coat percentage and EC value of seed leachate and seed weight in the cross *CM60* x *GC10848* showed higher than those in the cross *CM60* x *Kalitur*.

The seed coat percentage showed highly negative linear correlation with seed weight in both soybean crosses. The coefficient of determination (R^2) between the two seed characteristics were 0.831 and 0.652 in the crosses *CM60* x *GC10848* and *CM60* x *Kalitur* (Figure 6e and 6f), respectively. Therefore, the coefficient of determination between seed coat percentage and seed weight in the cross *CM60* x *GC10848* exhibited higher than the value in the cross *CM60* x *Kalitur*.

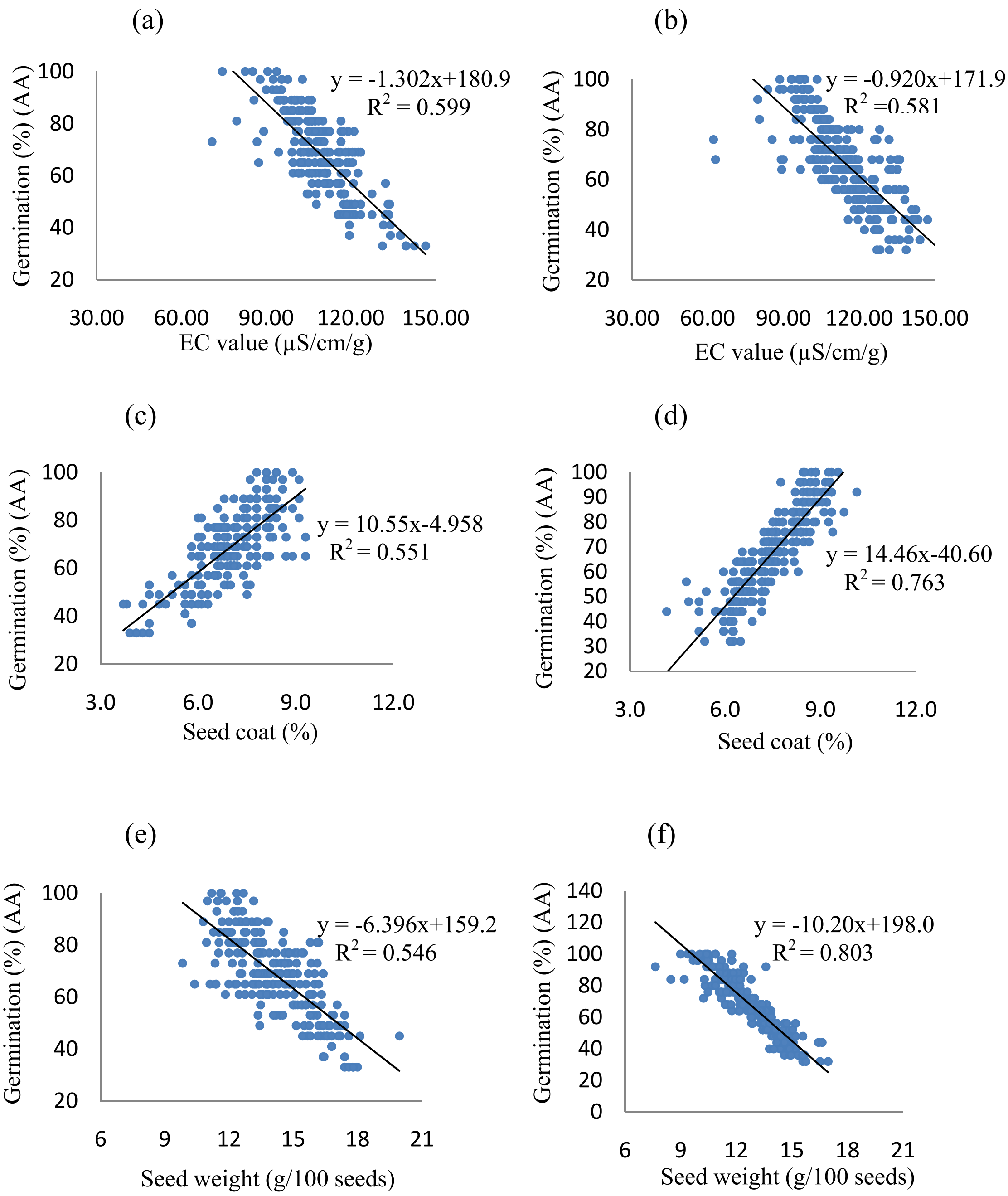

Figure 5 The linear correlations between germination percentage and EC value of seed leachate, seed coat percentage and seed weight of F_2 progenies of the crosses *CM 60* x *GC 10848* (a, c, e) and *CM 60* x *Kalitur* (b, d, f).

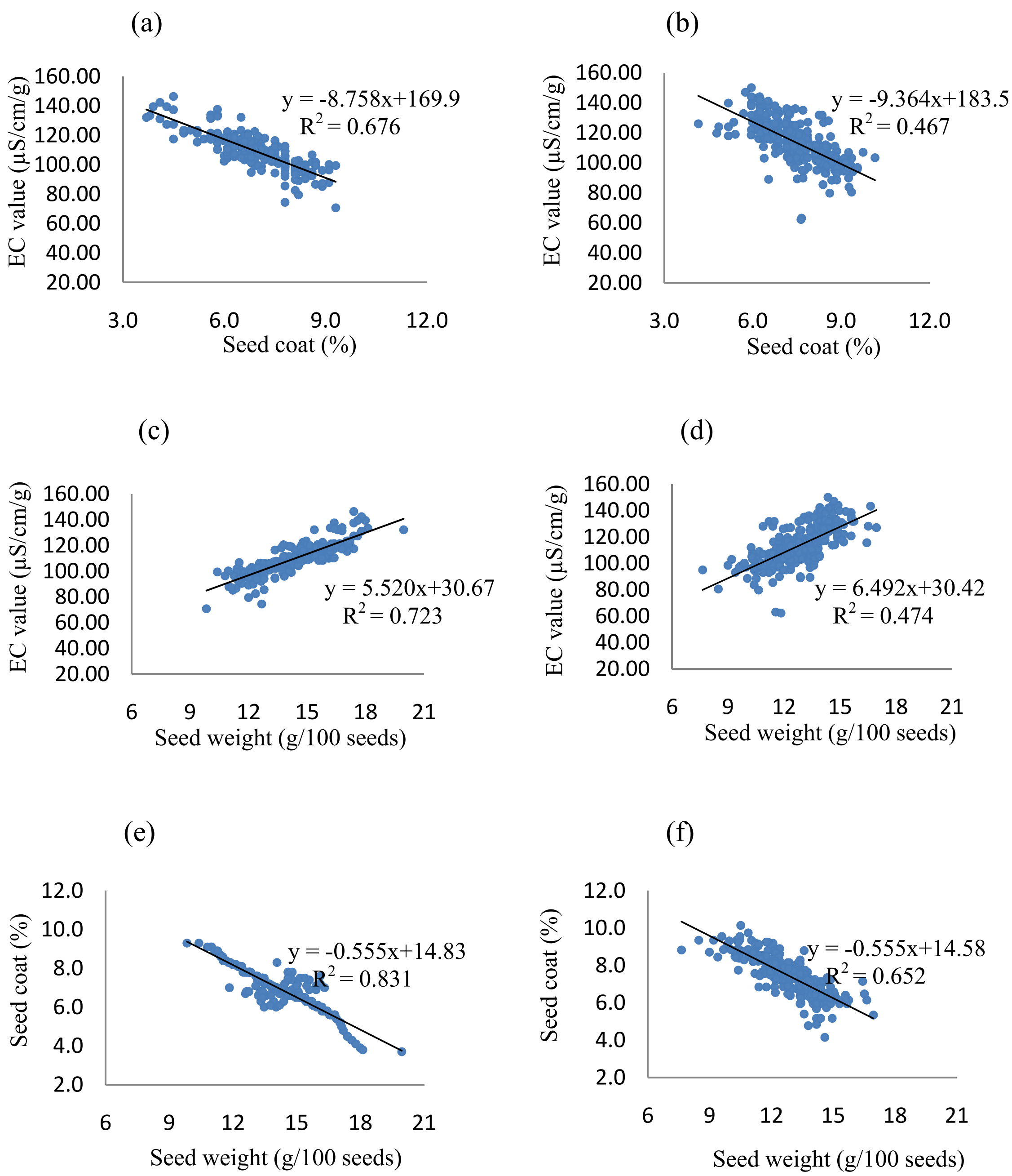

Figure 6 The linear correlations between EC value of seed leachate, seed coat percentage and seed weight of F2 progenies of the crosses *CM 60* x *GC 10848* (a, c, e) and *CM 60* x *Kalitur* (b, d, f).

Some morpho-agronomic characters of parents, F_1 plant and F_2 plants

Some morpho-agronomic characters of parents, F_1 and F_2 progenies of the two soybean crosses were illustrated in table 7. It was shown that some morpho-agronomic characters of F_1 hybrids exhibited dominance expression while some characters were intermediate between their parents in both crosses which revealed the hybridity of F_1 hybrids.

Table 7 Some morpho-agronomic characters of parents, F_1 plants and F_2 plants of two soybean crosses.

Population	No. of plant tested	Hypo -cotyl color	Flower color	Seed coat color	Stem termi-nation	Days to 50% flower -ing	Plant height (cm)
CM60xGC10848							
CM60	30	G	W	Y	Semi	32	34.5
GC10848	30	P	P	Br	Det.	26	8.5
F_1 plants	10	P	P	Ybr	Semi	30	16.2
F_2 plants	239	G, P	W, P	Ybr, Y, Br, Dbr	Det., semi	29	19.5
CM60xKalitur							
CM60	30	G	W	Y	Semi	32	34.5
Kalitur	30	P	P	Bl	Indet.	37	60.5
F_1 plants	30	P	P	G	Semi	35	41.5
F_2 plants	359	G, P	W, P	G, Y, Bl, Br	Indet., semi	36	44.5

G = Green, P = Purple, W = White, Y = Yellow, Br = Brown, Bl = Black
Ybr = Yellowish brown, Dbr = Dark brown,
Semi = Semi-determinate, Det = Determinate, Indet = Indeterminate

In both crosses, hypocotyls color of female parent *CM 60* was green whereas that of male parents *GC 10848* and *Kalitur* were purple. The F_1 hybrids of both crosses possessed purple color of hypocotyl which was dominant to the green color. The F_2 progenies of both crosses were segregated for purple and green color of hypocotyls with the ratio closely related to 3 : 1 (green : purple) (Figure 7 and 8). Furthermore, purple hypocotyl plants bore purple flowers and green hypocotyl plants bore white flowers. This result was in agreement with the findings of Woodworth (1923) that hypocotyl color was controlled by single pair of gene and purple was dominant to green.

In both crosses, flower color of female parent *CM 60* was white whereas that of female parents *GC 10848* and *Kalitur* were purple. The F_1 hybrids of both crosses possessed purple color of flower which was dominant to the white color. The F_2 progenies of both crosses were segregated for purple and white color of flower with the ratio closely related to 3 : 1 (purple : white) (Figure 9 and 10). This result was in consistent with the findings of Woodworth (1923) that flower color was controlled by single pair of gene and purple was dominant to white.

In the cross *CM60* x *GC10848*, seed coat color of *CM60* was yellow whereas that of male parent *GC 10848* was brown. The F_1 hybrid was yellowish brown in seed coat color which was intermediate between their parents. The yellowish brown, yellow, brown and dark brown color of seed coat were found in F_2 progenies (Figure 11). In the cross *CM60* x *Kalitur*, seed coat color of female parent *CM60* was yellow while that of male parent *Kalitur* was black. However, seed coat color of F_1 hybrid was green which was intermediate between their parents. The green, yellow, black and brown color of seed coat were observed in F_2 progenies (Figure 12). This result was similarly to the report of Ojo (2006) that four classes of seed coat color were found in the F_2 progenies of which their parents were yellow and black in seed coat color. However, the seed coat color had additive effect in this study although black seed coat color was dominant to the yellow ones according to the finding of Ojo (2006).

Stem growth habit in the cross *CM60* x *GC10848*, *CM60* was semi-determinate whereas that of *GC10848* was determinate. The F_1 hybrid was semi-determinate which was dominant to determinate stem type. Both stem determination and semi-determination were observed in the F_2 progenies. In the cross *CM60* x *Kalitur*,stem termination of *CM60* was semi-determinate whereas *Kalitur* was indeterminate. The F_1 hybrid was semi-determinate which was dominant to indeterminate stem type. Both stem indetermination and semi-determination were recovered in the F_2 progenies. It was concluded from both crosses that semi-determination was dominant to determination and indetermination of stem. This result was partly consistent with the finding of Bernard (1972) that semi-determination was dominant to indetermination whereas indetermination was dominant to determination of stem.

In the cross *CM60* x *GC10848*, the mean number of days to 50% flowering of *CM60* was 32 days whereas that of *GC10848* was 26 days. The mean number of days to 50% flowering of the F_1 hybrids was 30 days which was intermediate between their parents which had the value of 26 – 32 days. The number of days to 50% flowering of the F_2 progenies varied from 26 to 35 days with the mean of 29 days. In the cross *CM60* x *Kalitur*, the mean number of days to 50% flowering of *CM60* was 32 days whereas that of *Kalitur* was 37 days. The mean number of days to 50% flowering of the F_1 hybrids was 35 days which was intermediate between their parents which had the value of 32 – 37 days. The number of days to 50% flowering of the F_2 progenies varied from 29 to 49 days with the mean of 36 days. By considering the flowering of F_1 hybrids in both crosses, this character had additive effect and late flowering might be partial dominant to early flowering. It was in accordance with the result of Bernard (1971) that late flowering was partial dominant to early flowering.

In the cross *CM60* x *GC10848*, the mean plant height of *CM60* was 34.5 cm whereas that of *GC10848* was 8.5 cm. The mean plant height of F_1 hybrids was 16.2 cm which was intermediate between their parents which possessed the value of 8.5 – 34.5 cm. The plant height of the F_2 progenies ranged from 9 to 44 cm with mean value of 19.5 cm. In the cross *CM60* x *Kalitur*, the mean plant height of *CM60* was

34.5 cm whereas that of *Kalitur* was 60.5 cm. The mean plant height of F_1 hybrids was 41.5 cm which was intermediate between their parents which gave the value of 34.5 – 60.5 cm. The plant height of the F_2 progenies ranged from 18 to 80 cm with mean value of 44.5 cm. By considering the plant height of F_1 hybrids in both crosses, the tall plant height might be partial dominant to short plant height and showed additive gene effect. It was in agreement with the finding of Croissant and Torrie (1971) that plant height mainly had additive effect with small dominance variance.

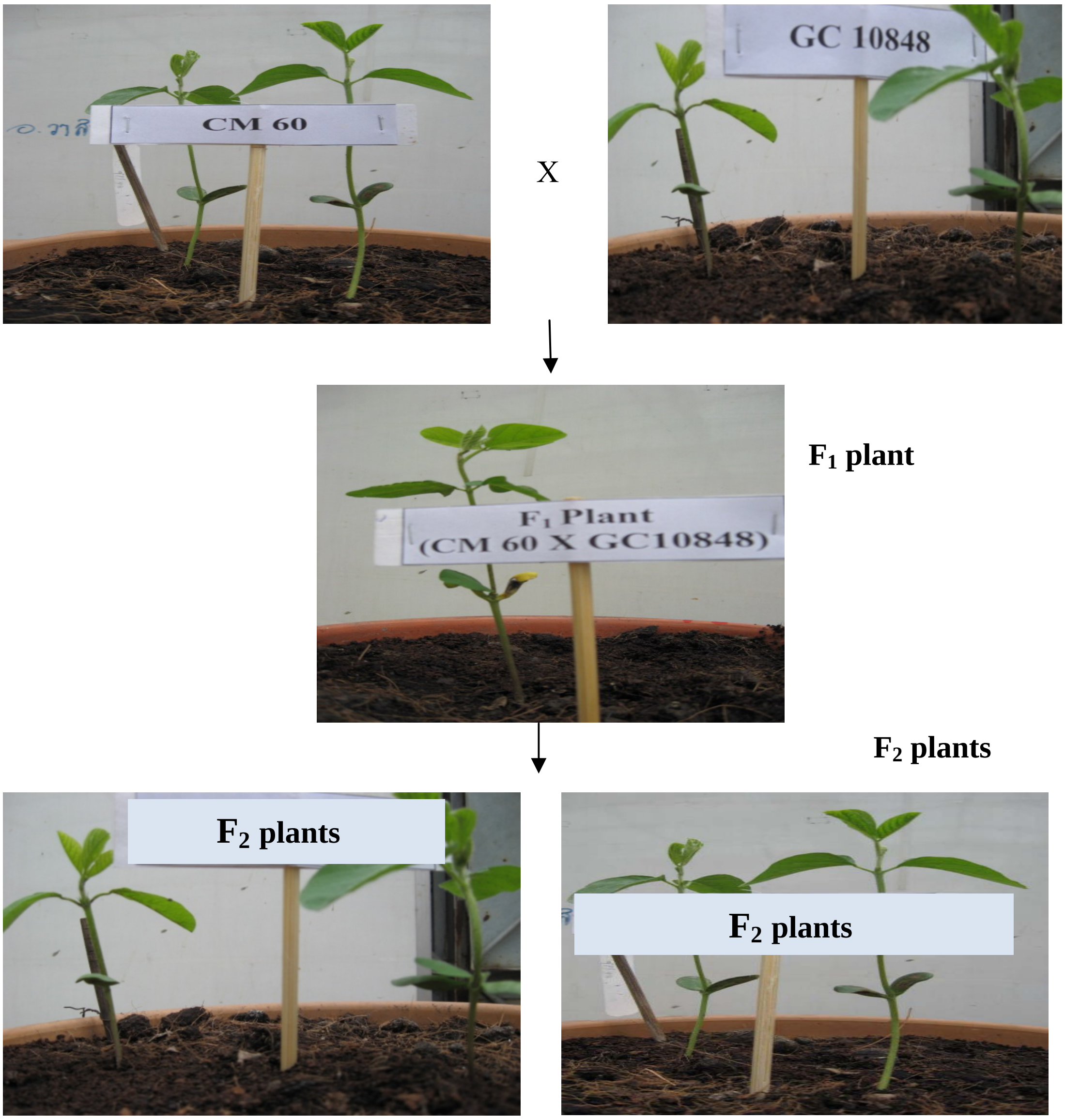

Figure 7 Hypocotyl color of parents, F_1 plant and F_2 plants of the cross *CM 60* x *GC 10848* (*CM60* = green, *GC10848* = purple, all F_1 s = purple, F_2 s = purple and green segregants).

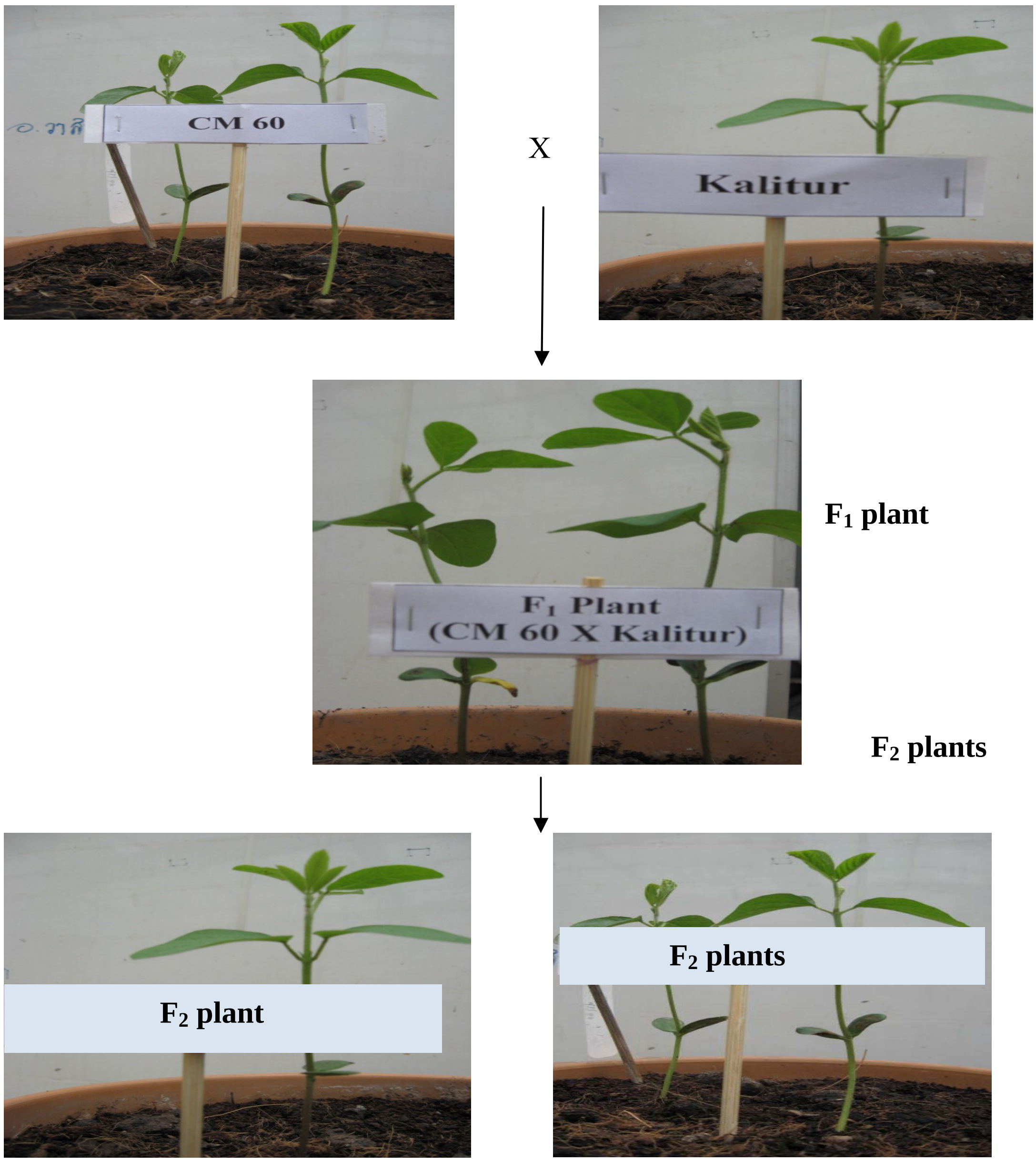

Figure 8 Hypocotyl color of parents, F_1 plant and F_2 plants of the cross *CM 60* x *Kalitur* (*CM60* = green, *Kalitur* = purple, all F_1 s = purple, F_2 s = purple and green segregants).

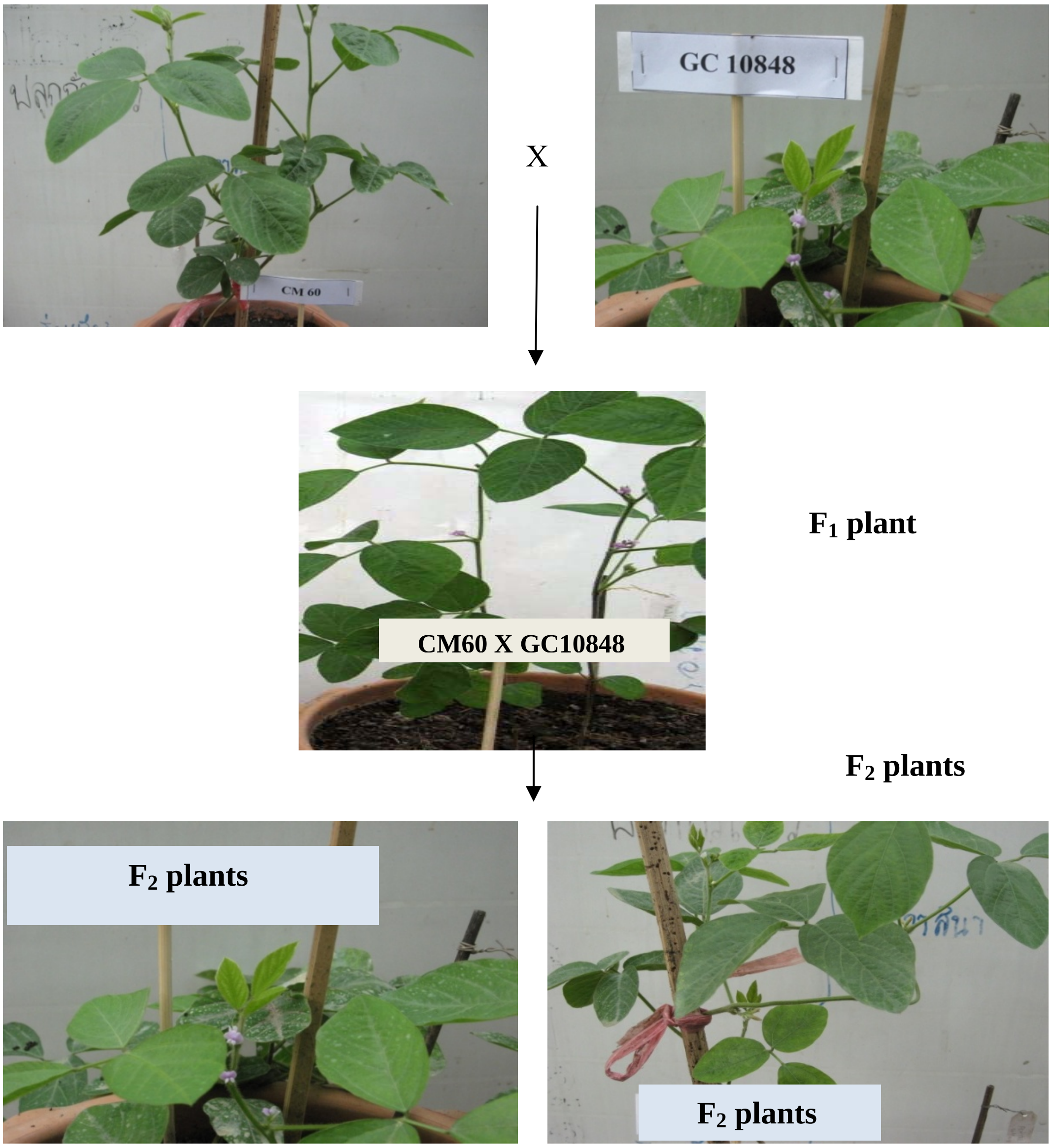

Figure 9 Flower color of parents, F_1 plant and F_2 plants of the cross *CM 60* x *GC 10848* (*CM60* = white, *GC10848* = purple, all F_1 s = purple, F_2 s = purple and white segregants).

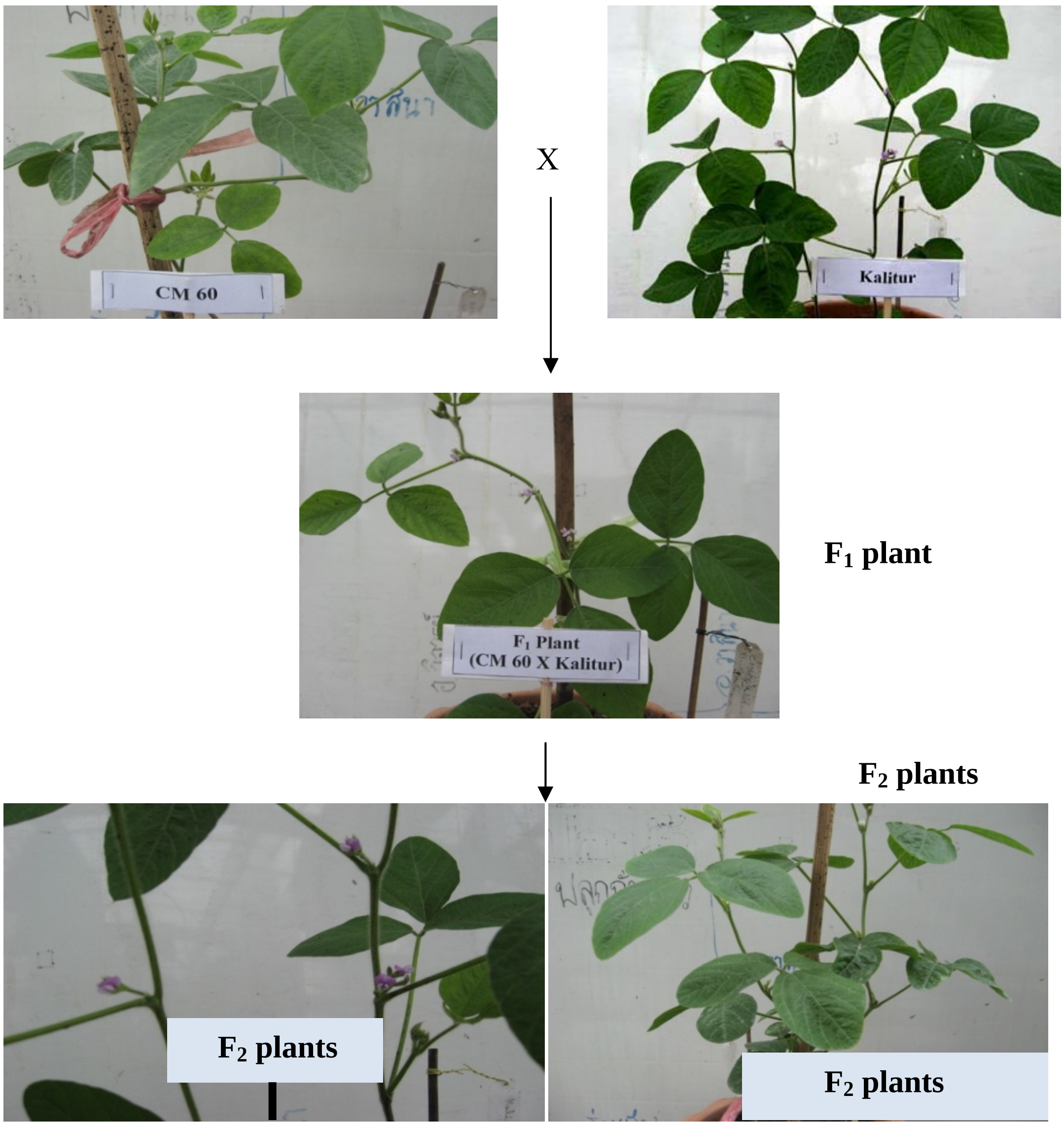

Figure 10 Flower color of parents, F_1 plant and F_2 plants of the cross *CM 60* x *Kalitur* (*CM60* = white, *Kalitur* = purple, all F_1 s = purple, F_2 s = purple and white segregants).

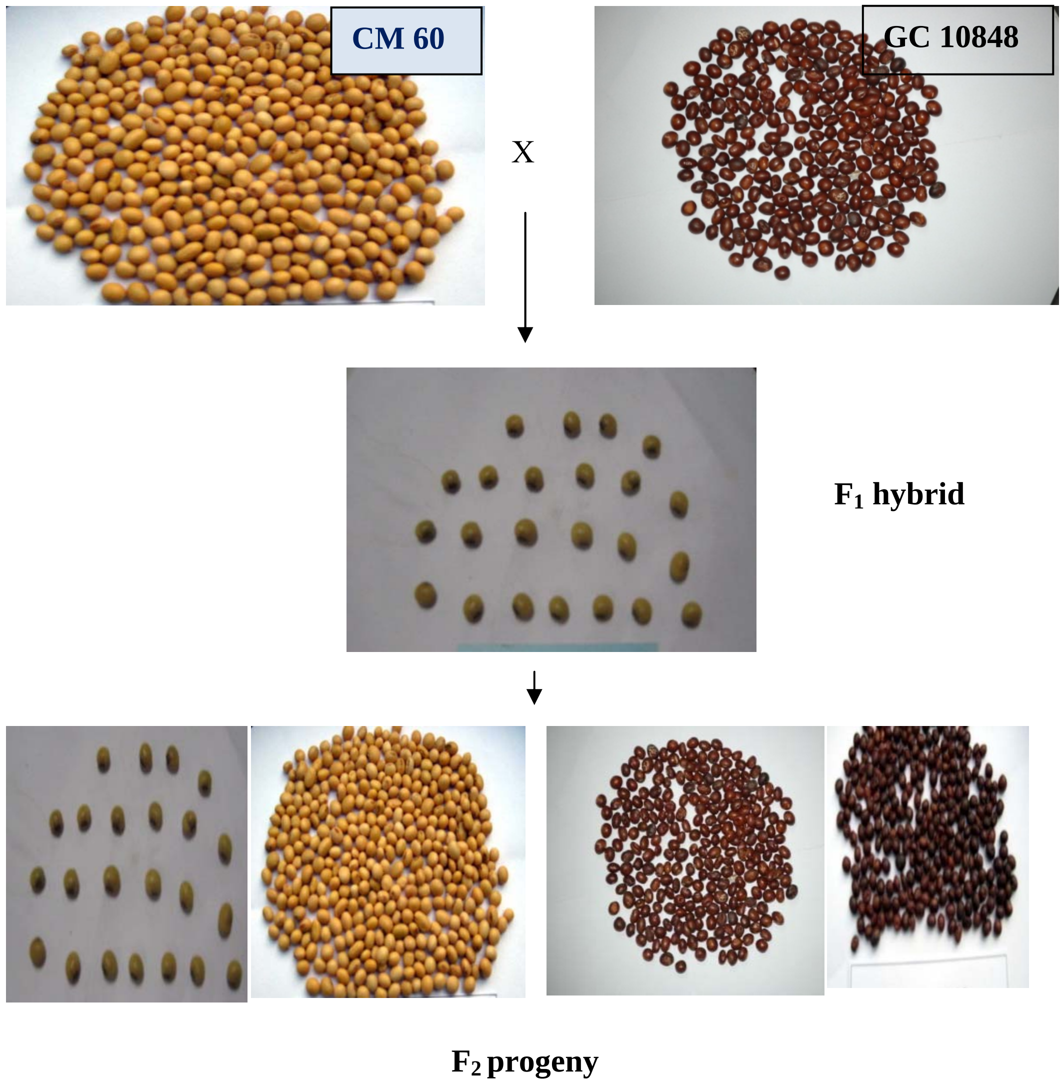

Figure 11 Seed coat color of parents, F_1 hybrid and F_2 progeny of the cross *CM 60* x *GC 10848* (*CM60* = yellow, *GC10848* = brown, all F_1 s = yellowish brown, F_2 s = yellowish brown,yellow, brown and dark brown segregants).

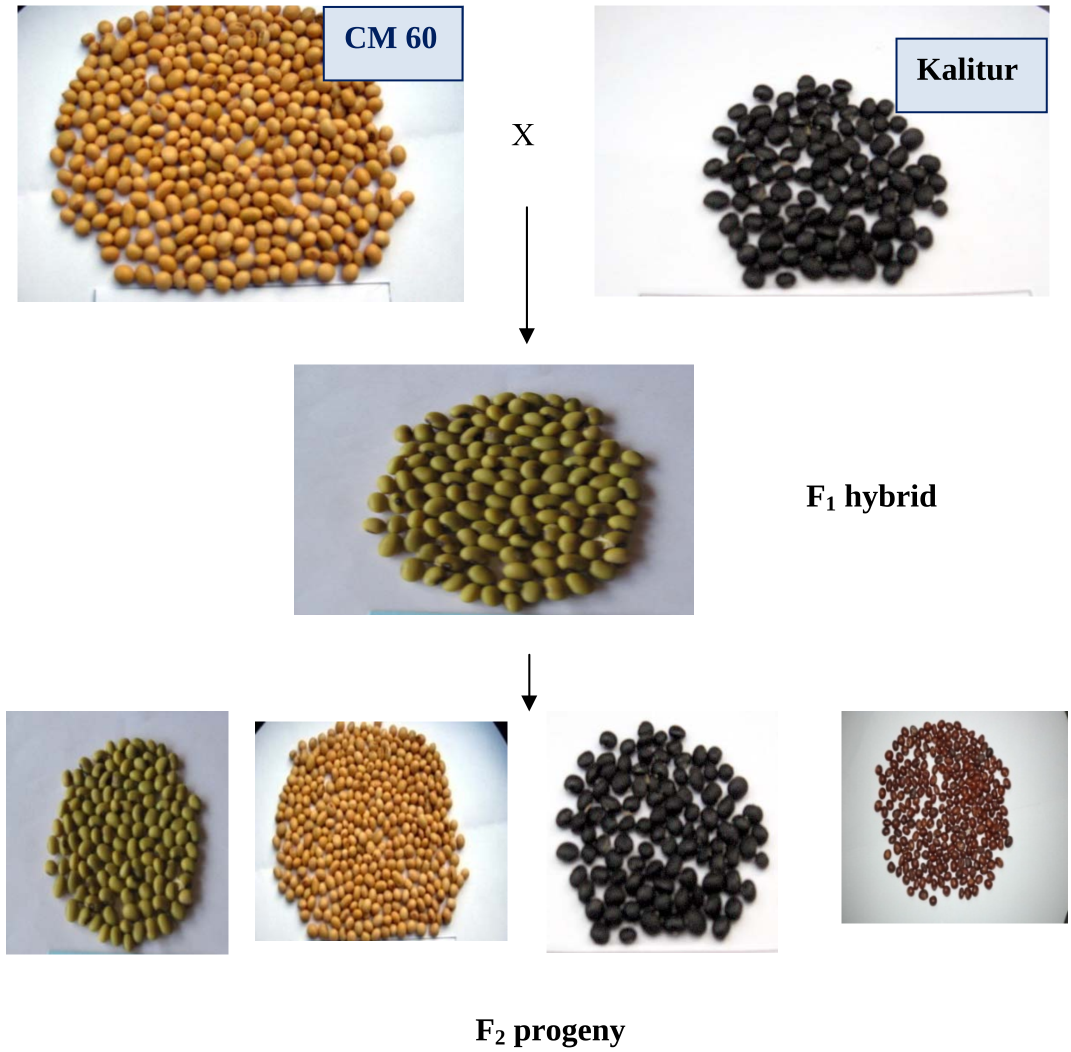

Figure 12 Seed coat color of parents, F$_1$ hybrid and F$_2$ progeny of the cross *CM 60* x *Kalitur* (*CM60* = yellow, *Kalitur* = black, all F$_1$ s = green, F$_2$ s = green,yellow, black and brown segregants).

Inheritance of some morphological characters

1. Inheritance of hypocotyl color

The inheritance of hypocotyls color was determined by phenotypic segregation of F_2 progenies of the two soybean crosses for hypocotyl color which was shown in Table 7 and 8. The 181 purple and 58 green hypocotyls were recovered among the total of 239 F_2 plants in the cross of *CM60* x *GC10848* while the 268 purple and 91 greem hypocotyls were identified among the total of 359 F_2 plants in the cross of *CM60* x *Kalitur*. In both cross, the F_2 progeny segregated into the ratio of 3 purple : 1 green offspring presenting a monogenic Mendelian ratio. The chi-square values were between 0.068 and 0.023 and P values were between 0.794 and 0.879 fitting to a monogenic Mendelian ratio at a very high level. This result was in accordance with the finding of Woodworth (1923) that hypocotyl color was controlled by single pair of gene and purple was dominant to green color.

Table 8 Phenotypic segregation of F_2 progenies for hypocotyl color in two soy bean crosses and their respective chi-square values against 3:1 expected ratio.

Crosses	No of tested plants	No. of plants (3 : 1 ratio)				Chi-square value	P value
		Purple		Green			
		Observ-ed	Expect-ed	Observ-ed	Expect-ed		
CM60xGC10848	239	181	179.5	58	59.5	0.068	0.794
CM60xKalitur	359	268	269.25	91	89.75	0.023	0.879

2. Inheritance of flower color

Inheritance of flower color was evaluated by phenotypic segregation of F_2 progenies of the two soybean crosses for flower color which was given in Table 7 and 9. The 181 purple and 58 white flower plants were observed among the total of 239 F_2

plants in the cross of *CM60* x *GC10848* whereas 268 purple and 91 white flower plants were found among the total of 359 F_2 plants in the cross of *CM60* x *Kalitur*. In both crosses, the F_2 population segregated into the ratio of 3 purple : 1 white flower color supporting a monogenic Mendelian ratio. The chi-square values were between 0.068 and 0.023 and P values were between 0.794 and 0.879 fitting to a monogenic Mendelian ratio at a very high level. This result was in accordance with the study of Woodworth (1923) that flower color was controlled by single pair of gene and purple was dominant to white color.

Table 9 Phenotypic segregation of F_2 progenies for flower color in two soybean crosses and their respective chi-square values against 3:1 expected ratio.

Crosses	No. of tested plants	No. of plants (3 : 1 ratio)				Chi-square value	P value
		Purple		white			
		Observ-ed	Expect-ed	Observ-ed	Expect-ed		
CM60xGC10848	239	181	179.5	58	59.5	0.068	0.794
CM60xKalitur	359	268	269.25	91	89.75	0.023	0.879

3. Inheritance of seed coat color

The inheritance of seed coat color was investigated by phenotypic segregation of F_2 progenies of the two soybean crosses for seed coat color which was manifested in Table 7 and 10. Among the total of 239 F_2 plants in the cross of *CM60* x *GC10848*, the plants with yellowish brown, yellow, brown and dark brown seed coat color were found to be 134, 48, 43 and 15 plants, respectively. The F_2 population segregated into the ratio of 9 yellowish brown : 3yellow : 3 brown : 1 black in seed coat color indicating digenic Mendelian ratio. Among the total of 359 F_2 plants in the cross of *CM60* x *Kalitur*, the plants having green, yellow, black and brown in seed coat color were observed to be 204, 65, 66 and 24 plants respectively. In this cross, the F_2 population also segregated into the ratio of 9 green : 3 yellow: 3 black : 1

brown in seed coat color presenting digenic Mendelian ratio. The chi-square values were between 0.360 and 0.235 and P values were between 0.950 and 0.972 fitting to digenic Mendelian ratio at a very high level. The results of both crosses were in agreement with the finding of Ojo (2006) that four classes of seed coat color were found in F_2 progenies of their female parent was yellow and their male parents were black seed coat color. However, there was additive gene effect on seed coat color in this study though black seed coat color was dominant to the yellow ones according to the finding of Ojo (2006).

Table 10 Phenotypic segregation of F_2 progenies for seed coat color in two soybean crosses and their respective chi-square values against 9:3:3:1 expected ratio.

Crosses	No. of test-ed	No. of plants (9 : 3 : 3 : 1 ratio)								Chi-square value	P value
		Ybr/G		Y		Br/Bl		Dbr/Br			
		O	E	O	E	O	E	O	E		
CM60 X GC10848	239	134 ybr	134.4 ybr	48 y	44.8 y	43 br	44.8 br	14 dbr	15.0 dbr	0.360	0.950
CM60 X Kalitur	359	204 g	202 g	65 y	67.3 y	66 bl	67.3 bl	24 br	22.4 br	0.235	0.972

O = Observed, E = Expected, Ybr = Yellow brown, G = Green, Y =Yellow,
Br = Brown, Bl = Black, Dbr = Dark brown

Heritability of some seed characteristics

The broad sense heritability (h^2) of some seed coat characteristics including germination percentage, EC value of seed leachate, seed coat percentage and seed weight attributed to field weathering resistance were shown in table 11. Heritability values of these parameters contributed to field weathering resistance were relatively high due to broad-sense heritability, particularly, germination percentage after AA test gave the highest average heritability. Narrow-sense heritability could not be measured at this time. Therefore, gene effect may appear at earlier generations. However, these parameters were governed by polygene and the heritability will increase with the advanced generation of breeding and the selections for these characters maybe more effective at later generation.

Table 11 Heritability (broad-sense) of some seed characteristics of two soybean crosses.

Crosses	Heritability (broad-sense)			
	Germination (%) (AA test)	EC value of seed leachate (µS/cm/g seed)	Seed coat (%)	Seed weight (g/100seeds)
CM60 x GC10848	81	70	86	82
CM60 x Kalitur	80	76	71	74
Average	80.5	73	78.5	78

CONCLUSION AND RECOMMENDATIONS

Conclusion

1. Inheritance of field weathering resistance in soybean was determined by dominance percentages of F_1 hybrids and the frequency distribution of F_2 progenies for germination percentages after AA test, EC values of seed leachate, seed coat percentages and seed weight of the two soybean crosses. The results revealed that field weathering resistance was controlled by polygene with partial dominance.

2. Correlations between some seed characteristics indicated that the seeds with high germination percentage and seed coat percentage but with low EC value of seed leachate and seed weight were contributed to field weathering resistance of soybean.

3. Inheritances of some morpho-agronomic characters were investigated by the mean value of F_1 hybrids and phenotypic segregation of the F_2 progenies of two soybean crosses. It was found that hypocotyl and flower color were controlled by single pair of gene. Seed coat color showed digenic inheritance. Semi-determinate was dominant to indeterminate whereas indeterminate was dominant to determinate type of stem. Late flowering and tall plant type might be partial dominant to early flowering and short plant type.

Recommendations

To improve field weathering resistant variety, selection can be done effectively from the cross between susceptible variety and resistant variety using evaluation measurement of seed characteristics including seed germination percentage, EC value of seed leachate, seed coat percentage and seed weight by pedigree or single seed decent method. Selection should be carefully emphasized on germination percentage which had the highest heritability in combination with other seed characteristics such as EC value of seed leachate (seed vigor), seed coat percentage and seed weight in F_2 – F_5 generations. From F_3 generation, the performance of good agronomic characters can be considered depending on the nature of responsible characters.

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APPENDICES

Appendix Table 1 Some seed characteristics including germination (%) after AA test, EC value of seed leachate, seed coat percentage, seed weight and seed coat color of parental varieties, F_1hybrids and F_2 progenies of the soybean cross *CM60* x *GC10848*.

Plant no.	Pedigree	Germination (%) (AA)	EC (µS/cm/g)	Seed coat (%)	100 seeds weight (g)	Seed coat color
1	CM60(P_1)	44	133.00	5.8	17.4	Y
2	CM60(P_1)	36	133.00	5.8	17.5	Y
3	CM60(P_1)	44	132.00	5.5	17.5	Y
4	CM60(P_1)	52	130.00	6.4	17	Y
5	CM60(P_1)	32	128.00	6.0	17.3	Y
6	CM60(P_1)	48	128.00	6.0	17.3	Y
7	CM60(P_1)	48	133.00	6.3	17.2	Y
8	CM60(P_1)	36	134.00	5.5	17.6	Y
9	CM60(P_1)	60	123.00	6.8	14.9	Y
10	CM60(P_1)	56	123.00	6.9	14.9	Y
11	CM60(P_1)	56	123.00	6.9	14.8	Y
12	CM60(P_1)	54	125.00	6.7	14.9	Y
13	CM60(P_1)	54	125.00	6.6	14.9	Y
14	CM60(P_1)	52	132.00	6.4	15.4	Y
15	CM60(P_1)	52	125.00	6.5	15.2	Y
16	CM60(P_1)	48	128.00	6.0	17.3	Y
17	CM60(P_1)	44	134.00	5.8	17.4	Y
18	CM60(P_1)	24	140.00	5.2	18.5	Y
19	CM60(P_1)	28	139.00	5.2	18.2	Y
20	CM60(P_1)	28	139.00	5.4	18	Y
21	CM60(P_1)	32	139.00	5.4	18	Y
22	CM60(P_1)	44	130.00	5.9	17.4	Y
23	CM60(P_1)	48	130.00	5.9	17.3	Y
24	CM60(P_1)	32	136.00	5.5	17.9	Y
25	CM60(P_1)	48	128.00	5.9	17.3	Y
26	CM60(P_1)	48	134.00	6.3	17.2	Y
27	CM60(P_1)	36	135.00	6.3	17.6	Y
28	CM60(P_1)	44	132.00	5.9	17.4	Y
29	CM60(P_1)	32	136.00	5.4	17.9	Y
30	CM60(P_1)	36	135.00	5.5	17.6	Y
1	GC10848(P_2)	98	67.09	7.9	11.7	Br
2	GC10848(P_2)	82	78.09	7.1	13.2	Br
3	GC10848(P_2)	90	78.09	7.7	12.4	Br
4	GC10848(P_2)	90	81.09	7.6	12.7	Br
5	GC10848(P_2)	98	64.09	8.2	11.6	Br
6	GC10848(P_2)	94	72.09	7.9	12.3	Br
7	GC10848(P_2)	86	82.09	7.4	12.9	Br
8	GC10848(P_2)	86	81.09	7.5	12.8	Br
9	GC10848(P_2)	86	82.09	7.5	12.8	Br
10	GC10848(P_2)	98	67.09	8.0	11.7	Br
11	GC10848(P_2)	102	67.09	8.1	11.7	Br

<u>Appendix Table 1</u> (Continued)

Plant no.	Pedigree	Germination (%) (AA)	EC (µS/cm/g)	Seed coat (%)	100 seeds weight (g)	Seed coat color
12	GC10848(P_2)	90	75.09	7.8	12.4	Br
13	GC10848(P_2)	86	84.09	7.6	13.4	Br
14	GC10848(P_2)	94	73.09	7.8	12.3	Br
15	GC10848(P_2)	86	83.09	7.1	13.2	Br
16	GC10848(P_2)	86	80.09	7.7	12.6	Br
17	GC10848(P_2)	90	75.09	7.8	12.4	Br
18	GC10848(P_2)	82	84.09	7.6	13.3	Br
19	GC10848(P_2)	90	78.09	7.6	12.4	Br
20	GC10848(P_2)	94	69.09	7.9	12.0	Br
21	GC10848(P_2)	86	78.09	7.7	12.0	Br
22	GC10848(P_2)	82	84.09	7.1	13.1	Br
23	GC10848(P_2)	90	72.09	7.9	12.3	Br
24	GC10848(P_2)	94	69.09	8.0	12.0	Br
25	GC10848(P_2)	82	91.09	7.3	13.4	Br
26	GC10848(P_2)	82	91.09	7.3	13.4	Br
27	GC10848(P_2)	82	84.09	7.0	13.3	Br
28	GC10848(P_2)	90	83.09	7.4	13.1	Br
29	GC10848(P_2)	82	90.09	6.9	13.4	Br
30	GC10848(P_2)	86	77.09	7.7	12.4	Br
1	$F_1(P_1/P_2)$	75	123.49	7.8	13.7	Y Br
2	$F_1(P_1/P_2)$	70	113.49	7.4	13.5	Y Br
3	$F_1(P_1/P_2)$	70	105.49	7.2	13.5	Y Br
4	$F_1(P_1/P_2)$	70	112.49	7.4	13.5	Y Br
5	$F_1(P_1/P_2)$	65	106.49	6.8	14.2	Y Br
6	$F_1(P_1/P_2)$	65	114.49	7	14.2	Y Br
7	$F_1(P_1/P_2)$	75	105.49	7.6	13.4	Y Br
8	$F_1(P_1/P_2)$	65	122.49	7	13.6	Y Br
9	$F_1(P_1/P_2)$	70	122.49	6.6	14.2	Y Br
10	$F_1(P_1/P_2)$	75	113.49	7.2	13.5	Y Br
1	$F_2(P_1/P_2)$	69	122.57	6.9	14.79	Y Br
2	$F_2(P_1/P_2)$	69	123.49	6.5	14.95	Y
3	$F_2(P_1/P_2)$	77	110.81	6.9	14.79	Y Br
4	$F_2(P_1/P_2)$	57	114.99	6.3	15.43	Y
5	$F_2(P_1/P_2)$	65	102.49	6.0	14.03	Y Br
6	$F_2(P_1/P_2)$	57	116.49	6.9	15.91	Y Br
7	$F_2(P_1/P_2)$	69	104.92	6.7	14.19	Y Br
8	$F_2(P_1/P_2)$	73	103.63	6.9	14.19	Y Br
9	$F_2(P_1/P_2)$	57	116.34	6.5	15.07	Y Br
10	$F_2(P_1/P_2)$	41	119.49	5.6	16.79	Y Br
11	$F_2(P_1/P_2)$	69	99.15	6.9	14.19	Y Br
12	$F_2(P_1/P_2)$	49	118.74	5.6	16.71	Br
13	$F_2(P_1/P_2)$	57	111.49	6.6	14.99	Y Br
14	$F_2(P_1/P_2)$	89	98.93	7.1	13.75	Y Br
15	$F_2(P_1/P_2)$	61	111.00	7.0	16.31	Y Br
16	$F_2(P_1/P_2)$	37	137.67	5.8	16.39	Y Br

Appendix Table 1 (Continued)

Plant no.	Pedigree	Germination (%) (AA)	EC (µS/cm/g)	Seed coat (%)	100 seeds weight (g)	Seed coat color
17	$F_2(P_1/P_2)$	69	104.64	6.1	14.19	Y Br
18	$F_2(P_1/P_2)$	61	104.98	6.1	13.83	Y
19	$F_2(P_1/P_2)$	69	121.49	5.8	16.39	Br
20	$F_2(P_1/P_2)$	89	100.93	7.6	13.07	Y Br
21	$F_2(P_1/P_2)$	37	119.49	5.8	16.39	Y Br
22	$F_2(P_1/P_2)$	61	116.49	7.1	15.91	Y Br
23	$F_2(P_1/P_2)$	77	121.12	6.7	14.75	Y Br
24	$F_2(P_1/P_2)$	81	100.24	9.1	10.95	Y Br
25	$F_2(P_1/P_2)$	61	111.49	6.9	14.39	Y
26	$F_2(P_1/P_2)$	57	114.99	6.6	14.99	Y Br
27	$F_2(P_1/P_2)$	69	102.37	7.4	13.15	Y Br
28	$F_2(P_1/P_2)$	77	109.99	6.8	15.07	Y
29	$F_2(P_1/P_2)$	77	119.04	6.7	14.19	Y Br
30	$F_2(P_1/P_2)$	49	107.74	7.5	13.43	Br
31	$F_2(P_1/P_2)$	85	104.99	7.4	13.27	Y Br
32	$F_2(P_1/P_2)$	65	115.33	6.6	14.67	Y Br
33	$F_2(P_1/P_2)$	53	116.49	6.9	14.39	Y Br
34	$F_2(P_1/P_2)$	73	109.99	7.4	14.79	Y
35	$F_2(P_1/P_2)$	33	139.49	3.9	17.99	Y
36	$F_2(P_1/P_2)$	69	106.24	7.4	13.31	Y Br
37	$F_2(P_1/P_2)$	85	98.74	7.8	12.71	Y Br
38	$F_2(P_1/P_2)$	81	98.51	7.8	12.63	Y Br
39	$F_2(P_1/P_2)$	73	116.49	6.1	15.83	Y Br
40	$F_2(P_1/P_2)$	69	115.53	6.8	14.43	Y Br
41	$F_2(P_1/P_2)$	89	99.99	8.4	11.67	Y Br
42	$F_2(P_1/P_2)$	89	100.62	7.8	12.79	D Br
43	$F_2(P_1/P_2)$	65	103.39	6.6	13.19	Y
44	$F_2(P_1/P_2)$	85	104.25	6.6	14.55	Y
45	$F_2(P_1/P_2)$	81	116.49	6.0	16.19	D Br
46	$F_2(P_1/P_2)$	93	95.24	8.6	11.43	Y Br
47	$F_2(P_1/P_2)$	93	95.43	8.1	12.23	D Br
48	$F_2(P_1/P_2)$	45	133.46	3.8	18.11	Y Br
49	$F_2(P_1/P_2)$	69	105.55	6.3	14.39	D Br
50	$F_2(P_1/P_2)$	65	109.06	6.9	15.59	Y
51	$F_2(P_1/P_2)$	73	99.99	7.8	12.63	Y Br
52	$F_2(P_1/P_2)$	69	102.24	7.5	13.39	Br
53	$F_2(P_1/P_2)$	77	111.49	7.1	13.87	Y Br
54	$F_2(P_1/P_2)$	81	110.07	7.2	16.11	Br
55	$F_2(P_1/P_2)$	61	99.49	7.0	11.83	Br
56	$F_2(P_1/P_2)$	57	106.24	6.0	13.47	Y Br
57	$F_2(P_1/P_2)$	101	93.74	8.4	11.61	Y Br
58	$F_2(P_1/P_2)$	73	100.09	8.3	14.07	Y Br
59	$F_2(P_1/P_2)$	49	121.45	5.2	17.07	Y Br
60	$F_2(P_1/P_2)$	89	102.49	7.8	12.47	Y Br
61	$F_2(P_1/P_2)$	53	104.49	6.9	14.19	Br

Appendix Table 1 (Continued)

Plant no.	Pedigree	Germination (%) (AA)	EC (µS/cm/g)	Seed coat (%)	100 seeds weight (g)	Seed coat color
62	$F_2(P_1/P_2)$	69	116.19	6.5	15.19	Y Br
63	$F_2(P_1/P_2)$	45	120.49	5.8	16.27	Y Br
64	$F_2(P_1/P_2)$	85	101.92	8.6	11.51	D Br
65	$F_2(P_1/P_2)$	77	116.49	6.6	14.75	Y Br
66	$F_2(P_1/P_2)$	85	99.49	8.2	11.99	Y
67	$F_2(P_1/P_2)$	85	101.49	7.8	12.79	Y Br
68	$F_2(P_1/P_2)$	77	106.49	7.2	13.47	Y
69	$F_2(P_1/P_2)$	73	107.74	6.6	14.71	D Br
70	$F_2(P_1/P_2)$	45	121.49	4.8	17.19	Y Br
71	$F_2(P_1/P_2)$	73	105.03	7.5	13.35	Br
72	$F_2(P_1/P_2)$	69	104.99	7.2	13.55	Y Br
73	$F_2(P_1/P_2)$	97	102.84	7.6	13.15	Y Br
74	$F_2(P_1/P_2)$	85	99.49	8.2	12.11	Y Br
75	$F_2(P_1/P_2)$	73	109.99	7.4	14.59	Y Br
76	$F_2(P_1/P_2)$	69	119.18	6.7	14.67	Y Br
77	$F_2(P_1/P_2)$	93	92.24	7.8	12.63	Y Br
78	$F_2(P_1/P_2)$	61	122.49	6.1	15.79	Y Br
79	$F_2(P_1/P_2)$	81	99.49	8.4	11.53	D Br
80	$F_2(P_1/P_2)$	33	142.42	4.1	17.79	Y Br
81	$F_2(P_1/P_2)$	45	120.49	5.8	16.43	Y Br
82	$F_2(P_1/P_2)$	85	97.24	7.8	12.79	Y Br
83	$F_2(P_1/P_2)$	61	111.49	7.0	14.07	D Br
84	$F_2(P_1/P_2)$	89	94.15	7.8	12.79	Y Br
85	$F_2(P_1/P_2)$	73	116.49	6.0	16.11	Y Br
86	$F_2(P_1/P_2)$	89	106.07	7.8	12.83	Y Br
87	$F_2(P_1/P_2)$	101	74.49	7.8	12.67	Y Br
88	$F_2(P_1/P_2)$	81	104.64	6.8	13.31	Br
89	$F_2(P_1/P_2)$	49	118.74	5.6	16.63	Y Br
90	$F_2(P_1/P_2)$	65	102.49	8.1	12.27	Y Br
91	$F_2(P_1/P_2)$	89	102.42	7.4	13.27	Y Br
92	$F_2(P_1/P_2)$	61	105.24	6.6	13.57	Y Br
93	$F_2(P_1/P_2)$	97	87.88	9.1	10.99	Y
94	$F_2(P_1/P_2)$	81	107.42	7.2	13.57	Y Br
95	$F_2(P_1/P_2)$	89	96.50	9.1	10.79	Br
96	$F_2(P_1/P_2)$	85	97.49	8.4	11.55	Y Br
97	$F_2(P_1/P_2)$	69	118.14	7.2	13.67	Y Br
98	$F_2(P_1/P_2)$	85	106.18	7.5	13.47	Y
99	$F_2(P_1/P_2)$	97	97.67	8.1	12.39	Br
100	$F_2(P_1/P_2)$	57	115.49	5.2	17.05	Y Br
101	$F_2(P_1/P_2)$	49	123.49	4.8	17.19	Y
102	$F_2(P_1/P_2)$	77	117.33	6.5	15.19	Y
103	$F_2(P_1/P_2)$	89	94.85	6.8	13.35	Y Br
104	$F_2(P_1/P_2)$	89	96.08	7.1	13.83	Y Br
105	$F_2(P_1/P_2)$	53	117.49	5.4	16.87	Y Br
106	$F_2(P_1/P_2)$	65	118.49	6.1	15.99	Y Br

Appendix Table 1 (Continued)

Plant no.	Pedigree	Germination (%) (AA)	EC (µS/cm/g)	Seed coat (%)	100 seeds weight (g)	Seed coat color
107	$F_2(P_1/P_2)$	65	107.24	6.8	13.27	Y Br
108	$F_2(P_1/P_2)$	65	103.39	7.2	13.71	D Br
109	$F_2(P_1/P_2)$	45	116.49	6.3	15.67	D Br
110	$F_2(P_1/P_2)$	77	89.15	8.2	11.99	Y Br
111	$F_2(P_1/P_2)$	65	102.69	7.6	13.11	D Br
112	$F_2(P_1/P_2)$	77	112.24	7.1	15.47	Y
113	$F_2(P_1/P_2)$	69	120.49	6.6	14.99	Y Br
114	$F_2(P_1/P_2)$	89	104.99	7.8	12.55	Br
115	$F_2(P_1/P_2)$	77	100.66	8.1	12.39	Br
116	$F_2(P_1/P_2)$	77	107.49	7.2	13.59	D Br
117	$F_2(P_1/P_2)$	65	119.49	7.0	14.07	D Br
118	$F_2(P_1/P_2)$	77	106.74	8.6	11.51	Y Br
119	$F_2(P_1/P_2)$	73	108.49	7.2	14.43	Y Br
120	$F_2(P_1/P_2)$	69	107.69	7.1	13.79	Y
121	$F_2(P_1/P_2)$	73	109.74	7.5	15.15	Y Br
122	$F_2(P_1/P_2)$	77	109.64	7.8	14.79	Y Br
123	$F_2(P_1/P_2)$	61	108.85	7.2	15.03	Y Br
124	$F_2(P_1/P_2)$	65	112.74	6.5	15.31	Y Br
125	$F_2(P_1/P_2)$	81	106.24	7.8	12.55	Y
126	$F_2(P_1/P_2)$	41	131.49	5.6	16.79	Y Br
127	$F_2(P_1/P_2)$	33	146.49	4.5	17.39	Y Br
128	$F_2(P_1/P_2)$	85	101.40	8.2	12.05	Y Br
129	$F_2(P_1/P_2)$	61	107.44	7.5	13.43	Br
130	$F_2(P_1/P_2)$	81	107.24	6.8	14.51	Br
131	$F_2(P_1/P_2)$	73	102.99	8.2	12.15	Y
132	$F_2(P_1/P_2)$	65	105.07	6.9	14.31	Y
133	$F_2(P_1/P_2)$	61	111.49	7.1	13.83	Y
134	$F_2(P_1/P_2)$	81	104.99	7.4	13.19	Br
135	$F_2(P_1/P_2)$	37	137.49	4.5	17.39	Y
136	$F_2(P_1/P_2)$	49	117.49	4.5	17.39	Y
137	$F_2(P_1/P_2)$	81	105.24	7.5	13.37	Y
138	$F_2(P_1/P_2)$	53	117.49	6.1	15.79	Br
139	$F_2(P_1/P_2)$	93	89.99	8.1	12.23	Y
140	$F_2(P_1/P_2)$	37	133.99	5.8	16.43	Y
141	$F_2(P_1/P_2)$	85	99.24	8.3	11.79	Y Br
142	$F_2(P_1/P_2)$	65	99.49	8.2	11.99	Y Br
143	$F_2(P_1/P_2)$	69	107.42	6.3	13.91	Br
144	$F_2(P_1/P_2)$	89	99.99	7.8	12.79	Y Br
145	$F_2(P_1/P_2)$	49	123.49	5.2	17.03	Y
146	$F_2(P_1/P_2)$	101	85.23	8.9	11.19	Y
147	$F_2(P_1/P_2)$	69	106.32	6.7	12.59	Y Br
148	$F_2(P_1/P_2)$	69	111.49	6.9	14.39	Y Br
149	$F_2(P_1/P_2)$	57	114.99	6.5	15.19	Y
150	$F_2(P_1/P_2)$	53	104.99	6.8	14.51	Y Br

Appendix Table 1 (Continued)

Plant no.	Pedigree	Germination (%) (AA)	EC (µS/cm/g)	Seed coat (%)	100 seeds weight (g)	Seed coat color
151	$F_2(P_1/P_2)$	101	90.58	8.4	11.63	Y
152	$F_2(P_1/P_2)$	89	96.24	8.1	12.31	Br
153	$F_2(P_1/P_2)$	81	106.24	7.5	13.39	Y Br
154	$F_2(P_1/P_2)$	77	107.74	6.5	13.39	Y Br
155	$F_2(P_1/P_2)$	97	92.49	8.6	11.47	Br
156	$F_2(P_1/P_2)$	57	120.87	6.3	15.55	Y Br
157	$F_2(P_1/P_2)$	73	109.99	7.4	14.59	Y Br
158	$F_2(P_1/P_2)$	49	119.49	6.3	15.51	Y Br
159	$F_2(P_1/P_2)$	73	86.78	8.7	11.35	Br
160	$F_2(P_1/P_2)$	73	108.99	7.8	14.59	Y
161	$F_2(P_1/P_2)$	81	101.49	8.1	12.31	Y
162	$F_2(P_1/P_2)$	81	97.49	8.1	12.27	Y Br
163	$F_2(P_1/P_2)$	53	112.42	7.6	16.11	Y Br
164	$F_2(P_1/P_2)$	53	116.49	7.5	13.35	Y
165	$F_2(P_1/P_2)$	49	120.12	6.6	15.13	Y Br
166	$F_2(P_1/P_2)$	61	118.42	6.7	14.67	Y
167	$F_2(P_1/P_2)$	41	133.99	5.6	16.79	Y
168	$F_2(P_1/P_2)$	65	112.64	7.8	14.59	D Br
169	$F_2(P_1/P_2)$	85	96.24	8.3	11.87	Br
170	$F_2(P_1/P_2)$	53	116.49	6.0	15.93	Br
171	$F_2(P_1/P_2)$	77	101.49	6.8	12.63	Br
172	$F_2(P_1/P_2)$	65	101.87	8.7	11.39	Y
173	$F_2(P_1/P_2)$	65	120.58	6.7	13.79	Y Br
174	$F_2(P_1/P_2)$	81	106.19	6.8	12.75	Y Br
175	$F_2(P_1/P_2)$	65	87.33	8.9	11.11	Y Br
176	$F_2(P_1/P_2)$	77	108.99	7.5	14.59	Y Br
177	$F_2(P_1/P_2)$	49	117.49	5.8	16.39	Y Br
178	$F_2(P_1/P_2)$	49	121.34	5.8	16.23	Y Br
179	$F_2(P_1/P_2)$	57	132.25	6.5	15.37	Y
180	$F_2(P_1/P_2)$	65	109.42	6.6	14.87	Y
181	$F_2(P_1/P_2)$	61	101.49	7.8	12.75	Y Br
182	$F_2(P_1/P_2)$	69	111.77	6.1	15.99	Y Br
183	$F_2(P_1/P_2)$	61	106.24	6.1	13.75	Br
184	$F_2(P_1/P_2)$	33	139.49	4.3	17.59	Y Br
185	$F_2(P_1/P_2)$	57	112.57	6.3	15.59	Y Br
186	$F_2(P_1/P_2)$	57	112.49	6.5	15.39	Y Br
187	$F_2(P_1/P_2)$	69	103.27	7.8	12.51	Y Br
188	$F_2(P_1/P_2)$	73	70.82	9.3	9.83	Y Br
189	$F_2(P_1/P_2)$	61	106.24	7.1	13.07	Y Br
190	$F_2(P_1/P_2)$	53	117.32	5.6	16.79	Y Br
191	$F_2(P_1/P_2)$	77	104.99	6.8	13.39	Br
192	$F_2(P_1/P_2)$	65	102.49	8.1	12.35	Y Br
193	$F_2(P_1/P_2)$	49	121.49	5.6	16.67	Y
194	$F_2(P_1/P_2)$	101	82.60	8.1	12.35	Br
195	$F_2(P_1/P_2)$	45	118.49	6.3	15.43	Y Br

Appendix Table 1 (Continued)

Plant no.	Pedigree	Germination (%) (AA)	EC (µS/cm/g)	Seed coat (%)	100 seeds weight (g)	Seed coat color
196	$F_2(P_1/P_2)$	45	115.49	6.1	15.79	Y Br
197	$F_2(P_1/P_2)$	77	112.49	6.6	14.79	Y Br
198	$F_2(P_1/P_2)$	65	99.49	9.3	10.39	Y Br
199	$F_2(P_1/P_2)$	65	102.49	7.8	12.75	Br
200	$F_2(P_1/P_2)$	65	111.49	6.6	13.79	Y Br
201	$F_2(P_1/P_2)$	81	98.78	8.2	12.11	Y Br
202	$F_2(P_1/P_2)$	97	95.49	8.3	11.87	Br
203	$F_2(P_1/P_2)$	53	117.83	6.1	15.79	Br
204	$F_2(P_1/P_2)$	61	102.49	7.8	12.47	Y Br
205	$F_2(P_1/P_2)$	65	110.49	7.1	14.99	Y Br
206	$F_2(P_1/P_2)$	81	108.49	6.1	15.79	Br
207	$F_2(P_1/P_2)$	65	115.99	6.6	14.79	Y
208	$F_2(P_1/P_2)$	57	108.49	7.4	15.59	Y Br
209	$F_2(P_1/P_2)$	73	110.49	6.8	14.59	Y Br
210	$F_2(P_1/P_2)$	69	112.49	6.3	15.71	Y
211	$F_2(P_1/P_2)$	65	99.49	8.7	11.39	Br
212	$F_2(P_1/P_2)$	45	119.49	5.6	16.59	Y Br
213	$F_2(P_1/P_2)$	85	96.24	8.9	11.27	Y Br
214	$F_2(P_1/P_2)$	61	101.49	7.8	12.75	Y Br
215	$F_2(P_1/P_2)$	61	110.49	6.1	15.75	Y
216	$F_2(P_1/P_2)$	57	110.49	5.8	16.31	Y Br
217	$F_2(P_1/P_2)$	77	107.42	6.3	13.31	Y Br
218	$F_2(P_1/P_2)$	53	127.49	4.5	17.39	Br
219	$F_2(P_1/P_2)$	89	94.99	8.2	11.99	Y Br
220	$F_2(P_1/P_2)$	45	132.24	5.6	16.55	Br
221	$F_2(P_1/P_2)$	69	110.49	5.8	16.39	Br
222	$F_2(P_1/P_2)$	45	123.49	5.0	17.11	Br
223	$F_2(P_1/P_2)$	65	114.99	5.8	16.19	Y
224	$F_2(P_1/P_2)$	49	118.49	6.1	15.75	Br
225	$F_2(P_1/P_2)$	49	133.74	5.8	16.19	Y
226	$F_2(P_1/P_2)$	53	107.69	7.0	14.07	Y
227	$F_2(P_1/P_2)$	93	93.74	8.1	12.41	Br
228	$F_2(P_1/P_2)$	69	94.43	7.5	13.35	Br
229	$F_2(P_1/P_2)$	49	133.11	5.8	16.39	Br
230	$F_2(P_1/P_2)$	81	79.56	8.2	11.99	Br
231	$F_2(P_1/P_2)$	77	112.48	7.5	15.39	Y
232	$F_2(P_1/P_2)$	45	117.49	5.6	16.79	Y Br
233	$F_2(P_1/P_2)$	45	127.49	4.3	17.59	Br
234	$F_2(P_1/P_2)$	33	131.20	4.1	17.79	Br
235	$F_2(P_1/P_2)$	45	118.49	6.0	16.15	Y Br
236	$F_2(P_1/P_2)$	85	102.74	7.4	13.19	Y Br
237	$F_2(P_1/P_2)$	89	85.66	7.8	12.79	Y Br
238	$F_2(P_1/P_2)$	45	132.24	3.7	19.95	Y Br
239	$F_2(P_1/P_2)$	65	104.99	6.5	13.39	Br

Y = yellow, Br = brown, Ybr = yellowish brown, Dbr = dark brown

Appendix Table 2 Some seed characteristics including germination (%) after AA test, EC value of seed leachate, seed coat percentage, seed weight and seed coat color of parental varieties, F_1 hybrids and F_2 progenies of the soybean cross *CM60 x Kalitur*.

Plant no.	Pedigree	Germination (%)(AA)	EC (µS/cm/g)	Seed coat (%)	100 seeds weight (g)	Seed coat color
1	CM60(P_1)	44	133.00	5.8	16.4	Y
2	CM60(P_1)	36	133.00	5.8	16.5	Y
3	CM60(P_1)	44	132.00	5.5	16.5	Y
4	CM60(P_1)	52	130.00	6.4	16	Y
5	CM60(P_1)	32	128.00	6.0	16.3	Y
6	CM60(P_1)	48	128.00	6.0	16.3	Y
7	CM60(P_1)	48	133.00	6.3	16.2	Y
8	CM60(P_1)	36	134.00	5.5	16.6	Y
9	CM60(P_1)	60	123.00	6.8	13.9	Y
10	CM60(P_1)	56	123.00	6.9	13.9	Y
11	CM60(P_1)	56	123.00	6.9	13.8	Y
12	CM60(P_1)	54	125.00	6.7	13.9	Y
13	CM60(P_1)	54	125.00	6.6	13.9	Y
14	CM60(P_1)	52	132.00	6.4	14.4	Y
15	CM60(P_1)	52	125.00	6.5	14.2	Y
16	CM60(P_1)	48	128.00	6.0	16.3	Y
17	CM60(P_1)	44	134.00	5.8	16.4	Y
18	CM60(P_1)	24	140.00	5.2	17.5	Y
19	CM60(P_1)	28	139.00	5.2	17.2	Y
20	CM60(P_1)	28	139.00	5.4	17	Y
21	CM60(P_1)	32	139.00	5.4	17	Y
22	CM60(P_1)	44	130.00	5.9	16.4	Y
23	CM60(P_1)	48	130.00	5.9	16.3	Y
24	CM60(P_1)	32	136.00	5.5	16.9	Y
25	CM60(P_1)	48	128.00	5.9	16.3	Y
26	CM60(P_1)	48	134.00	6.3	16.2	Y
27	CM60(P_1)	36	135.00	6.3	16.6	Y
28	CM60(P_1)	44	132.00	5.9	16.4	Y
29	CM60(P_1)	32	136.00	5.4	16.9	Y
30	CM60(P_1)	36	135.00	5.5	16.6	Y
1	Kalitur(P_3)	90	76.00	9.3	9.7	Bl
2	Kalitur(P_3)	82	92.00	7.4	10.7	Bl
3	Kalitur(P_3)	94	74.00	9.5	9.7	Bl
4	Kalitur(P_3)	84	89.00	8.3	10.6	Bl
5	Kalitur(P_3)	94	74.00	9.3	9.7	Bl
6	Kalitur(P_3)	90	80.00	8.3	10.6	Bl
7	Kalitur(P_3)	82	92.00	7.4	10.7	Bl
8	Kalitur(P_3)	88	84.00	8.5	9.8	Bl
9	Kalitur(P_3)	82	94.00	7.4	10.8	Bl
10	Kalitur(P_3)	88	80.00	8.8	9.8	Bl
11	Kalitur(P_3)	94	74.00	9.5	9.7	Bl

Appendix Table 2 (Continued)

Plant no.	Pedigree	Germination (%) (AA)	EC (µS/cm/g)	Seed coat (%)	100 seeds weight (g)	Seed coat color
12	Kalitur(P_3)	86	86.00	8.5	9.9	Bl
13	Kalitur(P_3)	84	94.00	7.5	10.7	Bl
14	Kalitur(P_3)	88	84.00	8.5	9.8	Bl
15	Kalitur(P_3)	90	76.00	9.3	9.7	Bl
16	Kalitur(P_3)	90	76.00	8.8	9.8	Bl
17	Kalitur(P_3)	88	84.00	8.5	10.5	Bl
18	Kalitur(P_3)	82	94.00	7.5	10.7	Bl
19	Kalitur(P_3)	82	94.00	7.5	10.7	Bl
20	Kalitur(P_3)	84	92.00	7.8	10.7	Bl
21	Kalitur(P_3)	84	89.00	7.8	10.7	Bl
22	Kalitur(P_3)	84	89.00	8.0	10.6	Bl
23	Kalitur(P_3)	84	92.00	7.8	10.6	Bl
24	Kalitur(P_3)	88	80.00	8.8	9.8	Bl
25	Kalitur(P_3)	86	86.00	8.5	10.5	Bl
26	Kalitur(P_3)	86	89.00	8.0	10.6	Bl
27	Kalitur(P_3)	86	86.00	8.3	10.5	Bl
28	Kalitur(P_3)	86	86.00	8.3	10.6	Bl
29	Kalitur(P_3)	88	84.00	8.8	9.8	Bl
30	Kalitur(P_3)	86	86.00	8.3	10.6	Bl
1	$F_1(P_1/P_3)$	60	129.31	7.5	12.3	G
2	$F_1(P_1/P_3)$	64	124.31	7.6	12.1	G
3	$F_1(P_1/P_3)$	72	116.31	8.1	11.8	G
4	$F_1(P_1/P_3)$	72	118.31	7.9	12	G
5	$F_1(P_1/P_3)$	68	119.31	7.8	12	G
6	$F_1(P_1/P_3)$	68	120.31	7.8	12	G
7	$F_1(P_1/P_3)$	60	128.31	7.5	12.3	G
8	$F_1(P_1/P_3)$	76	109.31	8.3	11.8	G
9	$F_1(P_1/P_3)$	72	113.31	8.1	11.8	G
10	$F_1(P_1/P_3)$	76	109.31	8.3	11.8	G
11	$F_1(P_1/P_3)$	68	122.31	8.1	12	G
12	$F_1(P_1/P_3)$	72	118.31	7.9	11.8	G
13	$F_1(P_1/P_3)$	64	124.31	7.6	12.1	G
14	$F_1(P_1/P_3)$	64	126.31	7.6	12.1	G
15	$F_1(P_1/P_3)$	68	121.31	7.7	12.1	G
16	$F_1(P_1/P_3)$	57	130.31	7.4	12.3	G
17	$F_1(P_1/P_3)$	64	127.31	7.6	12.1	G
18	$F_1(P_1/P_3)$	72	116.31	8.1	11.8	G
19	$F_1(P_1/P_3)$	72	118.31	7.9	11.8	G
20	$F_1(P_1/P_3)$	60	128.31	7.5	12.1	G
21	$F_1(P_1/P_3)$	64	122.31	7.7	12	G
22	$F_1(P_1/P_3)$	57	130.31	7.4	12.3	G
23	$F_1(P_1/P_3)$	76	113.31	8.4	11.6	G
24	$F_1(P_1/P_3)$	81	107.31	8.4	11.6	G
25	$F_1(P_1/P_3)$	68	121.31	7.7	12	G
26	$F_1(P_1/P_3)$	76	107.31	8.3	11.8	G

Appendix Table 2 (Continued)

Plant no.	Pedigree	Germination (%) (AA)	EC (µS/cm/g)	Seed coat (%)	100 seeds weight (g)	Seed coat color
27	$F_1(P_1/P_3)$	68	122.31	7.7	12	G
28	$F_1(P_1/P_3)$	76	115.31	7.7	12	G
29	$F_1(P_1/P_3)$	81	105.31	8.4	11.6	G
30	$F_1(P_1/P_3)$	81	105.31	8.5	11.6	G
1	$F_2(P_1/P_3)$	76	104.90	7.5	11.59	Bl
2	$F_2(P_1/P_3)$	84	80.57	9.4	8.47	G
3	$F_2(P_1/P_3)$	32	138.59	6.3	15.59	G
4	$F_2(P_1/P_3)$	64	112.09	7.9	12.79	G
5	$F_2(P_1/P_3)$	56	116.22	6.2	15.19	G
6	$F_2(P_1/P_3)$	64	116.59	6.9	11.75	G
7	$F_2(P_1/P_3)$	52	127.09	6.4	14.55	G
8	$F_2(P_1/P_3)$	64	103.93	7.2	13.39	G
9	$F_2(P_1/P_3)$	80	107.87	8.9	10.31	G
10	$F_2(P_1/P_3)$	68	116.59	7.9	12.55	Y
11	$F_2(P_1/P_3)$	64	111.38	6.9	12.15	Y
12	$F_2(P_1/P_3)$	64	106.34	6.8	13.35	G
13	$F_2(P_1/P_3)$	56	122.09	6.3	14.15	Y
14	$F_2(P_1/P_3)$	84	103.03	9.4	9.19	Br
15	$F_2(P_1/P_3)$	68	63.14	7.7	11.55	Bl
16	$F_2(P_1/P_3)$	68	112.09	7.4	12.19	G
17	$F_2(P_1/P_3)$	76	96.59	8.4	11.07	Bl
18	$F_2(P_1/P_3)$	76	85.52	8.4	11.39	Bl
19	$F_2(P_1/P_3)$	68	101.34	8.2	13.31	Y
20	$F_2(P_1/P_3)$	52	120.81	6.7	14.11	Y
21	$F_2(P_1/P_3)$	76	93.97	9.4	10.47	Bl
22	$F_2(P_1/P_3)$	56	134.09	6.8	14.03	G
23	$F_2(P_1/P_3)$	72	112.09	8.5	10.23	G
24	$F_2(P_1/P_3)$	68	101.59	8.2	12.23	G
25	$F_2(P_1/P_3)$	60	108.84	8.3	13.39	G
26	$F_2(P_1/P_3)$	56	119.69	7.2	13.31	G
27	$F_2(P_1/P_3)$	64	110.21	8.2	12.11	G
28	$F_2(P_1/P_3)$	56	117.05	6.7	14.19	G
29	$F_2(P_1/P_3)$	56	110.65	6.8	13.37	Br
30	$F_2(P_1/P_3)$	92	98.09	8.5	10.55	Y
31	$F_2(P_1/P_3)$	96	98.09	8.4	10.43	Y
32	$F_2(P_1/P_3)$	72	105.90	7.6	11.19	Bl
33	$F_2(P_1/P_3)$	52	118.33	7.2	13.87	Y
34	$F_2(P_1/P_3)$	68	116.88	7.3	12.47	Y
35	$F_2(P_1/P_3)$	48	119.72	6.6	14.87	Y
36	$F_2(P_1/P_3)$	84	106.59	8.5	11.15	Y
37	$F_2(P_1/P_3)$	92	103.43	10.1	10.51	Bl
38	$F_2(P_1/P_3)$	60	107.79	7.2	13.63	Y
39	$F_2(P_1/P_3)$	72	103.33	7.9	12.87	G
40	$F_2(P_1/P_3)$	100	93.27	8.5	9.39	Br
41	$F_2(P_1/P_3)$	64	89.35	7.5	13.39	Bl

Appendix Table 2 (Continued)

Plant no.	Pedigree	Germination (%) (AA)	EC (µS/cm/g)	Seed coat (%)	100 seeds weight (g)	Seed coat color
42	$F_2(P_1/P_3)$	100	98.59	8.7	8.99	G
43	$F_2(P_1/P_3)$	56	134.09	7.1	14.11	Y
44	$F_2(P_1/P_3)$	96	88.52	8.7	10.51	Y
45	$F_2(P_1/P_3)$	76	62.33	7.6	11.83	Bl
46	$F_2(P_1/P_3)$	92	95.09	8.8	10.75	G
47	$F_2(P_1/P_3)$	68	101.95	7.5	13.63	Bl
48	$F_2(P_1/P_3)$	44	115.64	7.1	16.43	G
49	$F_2(P_1/P_3)$	68	125.09	7.5	12.91	Y
50	$F_2(P_1/P_3)$	84	97.16	7.9	11.71	Bl
51	$F_2(P_1/P_3)$	44	119.53	6.5	15.07	Y
52	$F_2(P_1/P_3)$	56	121.10	7.1	14.19	G
53	$F_2(P_1/P_3)$	84	104.66	8.1	12.23	G
54	$F_2(P_1/P_3)$	72	104.66	7.5	12.99	Bl
55	$F_2(P_1/P_3)$	56	113.84	7.1	14.59	Br
56	$F_2(P_1/P_3)$	84	95.09	8.2	12.11	G
57	$F_2(P_1/P_3)$	88	100.42	8.3	12.39	Bl
58	$F_2(P_1/P_3)$	88	95.34	8.5	12.35	Bl
59	$F_2(P_1/P_3)$	64	96.80	7.4	13.39	Br
60	$F_2(P_1/P_3)$	68	106.92	8.2	12.87	G
61	$F_2(P_1/P_3)$	56	136.09	7.4	13.31	Y
62	$F_2(P_1/P_3)$	48	131.09	6.3	15.07	Y
63	$F_2(P_1/P_3)$	96	95.09	7.7	10.39	G
64	$F_2(P_1/P_3)$	92	95.09	8.8	7.63	G
65	$F_2(P_1/P_3)$	72	108.30	7.4	12.19	G
66	$F_2(P_1/P_3)$	60	108.59	7.3	13.39	Bl
67	$F_2(P_1/P_3)$	64	114.27	7.2	13.39	Br
68	$F_2(P_1/P_3)$	68	111.09	7.3	13.39	Br
69	$F_2(P_1/P_3)$	56	111.42	6.9	13.83	G
70	$F_2(P_1/P_3)$	64	110.84	6.4	13.39	G
71	$F_2(P_1/P_3)$	40	126.09	6.2	14.63	G
72	$F_2(P_1/P_3)$	100	103.35	9.4	10.31	G
73	$F_2(P_1/P_3)$	92	79.83	8.6	10.63	Bl
74	$F_2(P_1/P_3)$	84	106.09	8.6	11.11	G
75	$F_2(P_1/P_3)$	68	116.32	7.4	11.43	G
76	$F_2(P_1/P_3)$	64	119.56	6.5	12.19	Y
77	$F_2(P_1/P_3)$	84	107.48	8.3	11.19	Br
78	$F_2(P_1/P_3)$	68	128.09	6.9	11.39	G
79	$F_2(P_1/P_3)$	44	126.29	6.2	14.19	G
80	$F_2(P_1/P_3)$	56	113.59	6.9	12.83	Bl
81	$F_2(P_1/P_3)$	72	115.09	7.4	12.11	G
82	$F_2(P_1/P_3)$	88	105.05	8.7	11.19	G
83	$F_2(P_1/P_3)$	56	111.43	6.9	12.87	G
84	$F_2(P_1/P_3)$	56	115.77	6.3	13.87	G
85	$F_2(P_1/P_3)$	64	113.59	6.9	12.59	G
86	$F_2(P_1/P_3)$	68	115.09	7.9	11.71	G

Appendix Table 2 (Continued)

Plant no.	Pedigree	Germination (%) (AA)	EC (µS/cm/g)	Seed coat (%)	100 seeds weight (g)	Seed coat color
87	$F_2(P_1/P_3)$	64	135.09	6.9	13.87	Bl
88	$F_2(P_1/P_3)$	76	101.09	7.6	11.67	G
89	$F_2(P_1/P_3)$	88	105.84	8.5	11.59	G
90	$F_2(P_1/P_3)$	92	98.59	8.8	13.59	Bl
91	$F_2(P_1/P_3)$	68	136.09	7.1	13.35	G
92	$F_2(P_1/P_3)$	56	122.41	6.3	13.95	Y
93	$F_2(P_1/P_3)$	80	108.98	8.3	10.67	G
94	$F_2(P_1/P_3)$	80	108.98	8.3	11.79	G
95	$F_2(P_1/P_3)$	44	132.65	6.2	14.67	G
96	$F_2(P_1/P_3)$	80	115.41	7.7	12.07	Y
97	$F_2(P_1/P_3)$	32	131.96	6.2	15.75	G
98	$F_2(P_1/P_3)$	40	122.09	6.2	15.19	G
99	$F_2(P_1/P_3)$	88	98.09	8.4	11.35	G
100	$F_2(P_1/P_3)$	52	118.75	6.3	13.99	Y
101	$F_2(P_1/P_3)$	72	108.15	7.7	12.87	G
102	$F_2(P_1/P_3)$	84	108.15	8.2	11.35	G
103	$F_2(P_1/P_3)$	64	110.12	7.6	13.75	G
104	$F_2(P_1/P_3)$	48	129.55	6.2	15.19	G
105	$F_2(P_1/P_3)$	52	121.53	6.8	14.87	Bl
106	$F_2(P_1/P_3)$	60	108.59	7.2	13.51	Y
107	$F_2(P_1/P_3)$	52	119.09	7.3	14.87	G
108	$F_2(P_1/P_3)$	56	114.09	7.4	14.71	G
109	$F_2(P_1/P_3)$	60	120.50	7.2	13.51	Br
110	$F_2(P_1/P_3)$	68	118.51	7.7	13.39	G
111	$F_2(P_1/P_3)$	68	118.51	7.6	12.87	Bl
112	$F_2(P_1/P_3)$	80	108.71	8.2	12.19	G
113	$F_2(P_1/P_3)$	44	143.34	6.2	16.63	G
114	$F_2(P_1/P_3)$	68	89.09	6.5	12.87	Y
115	$F_2(P_1/P_3)$	84	107.19	8.4	11.23	Y
116	$F_2(P_1/P_3)$	80	105.02	8.2	11.75	G
117	$F_2(P_1/P_3)$	32	128.26	6.5	16.51	Y
118	$F_2(P_1/P_3)$	88	98.09	8.4	11.47	G
119	$F_2(P_1/P_3)$	92	97.75	9.4	10.39	G
120	$F_2(P_1/P_3)$	76	104.31	7.5	12.15	Bl
121	$F_2(P_1/P_3)$	92	96.10	9.4	11.03	Bl
122	$F_2(P_1/P_3)$	80	109.58	8.4	11.63	G
123	$F_2(P_1/P_3)$	64	115.09	7.3	12.67	G
124	$F_2(P_1/P_3)$	72	109.01	7.5	12.55	G
125	$F_2(P_1/P_3)$	64	114.01	7.3	12.79	G
126	$F_2(P_1/P_3)$	52	118.27	6.6	15.03	G
127	$F_2(P_1/P_3)$	48	120.84	6.4	15.59	G
128	$F_2(P_1/P_3)$	84	105.33	8.4	10.27	Bl
129	$F_2(P_1/P_3)$	36	144.09	6.0	14.59	Y
130	$F_2(P_1/P_3)$	68	89.97	7.7	12.87	Bl
131	$F_2(P_1/P_3)$	44	133.34	6.5	14.79	G

Appendix Table 2 (Continued)

Plant no.	Pedigree	Germination (%) (AA)	EC (µS/cm/g)	Seed coat (%)	100 seeds weight (g)	Seed coat color
132	$F_2(P_1/P_3)$	52	115.70	6.8	13.77	G
133	$F_2(P_1/P_3)$	60	119.01	6.9	13.31	G
134	$F_2(P_1/P_3)$	56	119.19	6.8	13.43	G
135	$F_2(P_1/P_3)$	60	113.84	6.9	13.31	G
136	$F_2(P_1/P_3)$	64	131.69	7.2	12.79	Bl
137	$F_2(P_1/P_3)$	56	130.84	6.5	13.79	G
138	$F_2(P_1/P_3)$	36	139.34	6.0	15.31	G
139	$F_2(P_1/P_3)$	56	138.09	6.5	13.79	G
140	$F_2(P_1/P_3)$	68	101.96	7.7	13.63	Bl
141	$F_2(P_1/P_3)$	40	128.09	6.2	14.79	Y
142	$F_2(P_1/P_3)$	76	126.96	8.4	12.15	G
143	$F_2(P_1/P_3)$	48	132.75	6.9	14.39	G
144	$F_2(P_1/P_3)$	64	114.09	7.6	13.39	Bl
145	$F_2(P_1/P_3)$	64	111.59	7.5	13.39	Bl
146	$F_2(P_1/P_3)$	60	110.58	7.5	13.33	G
147	$F_2(P_1/P_3)$	44	138.59	6.5	14.59	G
148	$F_2(P_1/P_3)$	36	144.09	6.2	14.89	G
149	$F_2(P_1/P_3)$	48	126.09	7.2	14.39	Bl
150	$F_2(P_1/P_3)$	68	111.59	8.1	13.39	G
151	$F_2(P_1/P_3)$	48	126.09	7.2	14.19	G
152	$F_2(P_1/P_3)$	56	117.65	7.3	14.11	G
153	$F_2(P_1/P_3)$	44	141.09	6.5	14.39	G
154	$F_2(P_1/P_3)$	60	106.59	7.2	13.59	G
155	$F_2(P_1/P_3)$	84	103.59	8.2	12.79	G
156	$F_2(P_1/P_3)$	64	106.09	7.6	13.43	Bl
157	$F_2(P_1/P_3)$	88	103.34	8.6	12.39	G
158	$F_2(P_1/P_3)$	88	101.59	8.6	12.39	G
159	$F_2(P_1/P_3)$	88	102.09	8.9	12.39	G
160	$F_2(P_1/P_3)$	92	98.59	8.9	12.39	G
161	$F_2(P_1/P_3)$	68	118.75	7.8	13.03	Bl
162	$F_2(P_1/P_3)$	68	111.09	7.6	13.32	Y
163	$F_2(P_1/P_3)$	56	120.67	7.2	14.03	G
164	$F_2(P_1/P_3)$	52	121.59	6.7	14.19	Bl
165	$F_2(P_1/P_3)$	60	120.84	7.2	13.79	G
166	$F_2(P_1/P_3)$	68	118.52	7.6	13.32	Bl
167	$F_2(P_1/P_3)$	64	116.09	7.4	13.63	G
168	$F_2(P_1/P_3)$	64	116.09	7.4	13.63	G
169	$F_2(P_1/P_3)$	68	116.09	7.6	13.32	G
170	$F_2(P_1/P_3)$	60	106.34	7.3	13.89	G
171	$F_2(P_1/P_3)$	68	117.34	7.4	13.32	G
172	$F_2(P_1/P_3)$	64	104.09	7.2	13.63	Bl
173	$F_2(P_1/P_3)$	44	147.09	5.7	14.67	G
174	$F_2(P_1/P_3)$	68	115.09	7.8	13.07	G
175	$F_2(P_1/P_3)$	88	95.09	9.2	11.23	Bl
176	$F_2(P_1/P_3)$	88	103.53	9.2	12.07	G

Appendix Table 2 (Continued)

Plant no.	Pedigree	Germination (%) (AA)	EC (µS/cm/g)	Seed coat (%)	100 seeds weight (g)	Seed coat color
177	$F_2(P_1/P_3)$	72	117.55	8.6	12.27	Bl
178	$F_2(P_1/P_3)$	60	105.11	7.2	13.89	Y
179	$F_2(P_1/P_3)$	72	109.79	8.1	12.27	G
180	$F_2(P_1/P_3)$	68	112.09	7.7	13.07	Y
181	$F_2(P_1/P_3)$	68	135.09	7.7	13.07	Y
182	$F_2(P_1/P_3)$	64	119.92	7.6	13.59	G
183	$F_2(P_1/P_3)$	64	135.09	7.3	13.59	Br
184	$F_2(P_1/P_3)$	40	150.09	6.0	14.35	G
185	$F_2(P_1/P_3)$	72	105.80	8.2	12.27	G
186	$F_2(P_1/P_3)$	72	104.13	8.2	12.15	G
187	$F_2(P_1/P_3)$	60	108.59	7.2	13.51	G
188	$F_2(P_1/P_3)$	60	109.19	7.3	13.51	G
189	$F_2(P_1/P_3)$	68	119.71	7.4	12.67	G
190	$F_2(P_1/P_3)$	68	132.38	7.3	12.91	G
191	$F_2(P_1/P_3)$	56	118.91	6.4	13.71	Y
192	$F_2(P_1/P_3)$	84	107.08	9.7	10.87	G
193	$F_2(P_1/P_3)$	68	114.09	7.3	13.39	Bl
194	$F_2(P_1/P_3)$	56	125.09	7.3	13.51	G
195	$F_2(P_1/P_3)$	84	103.13	9.1	11.23	Bl
196	$F_2(P_1/P_3)$	72	112.09	8.3	12.31	G
197	$F_2(P_1/P_3)$	48	142.42	6.3	13.91	G
198	$F_2(P_1/P_3)$	48	140.84	6.3	13.99	Y
199	$F_2(P_1/P_3)$	80	111.91	8.3	11.59	G
200	$F_2(P_1/P_3)$	52	120.45	6.8	13.71	Y
201	$F_2(P_1/P_3)$	72	113.63	7.7	12.31	G
202	$F_2(P_1/P_3)$	80	111.97	8.1	11.79	G
203	$F_2(P_1/P_3)$	52	126.09	6.7	13.71	G
204	$F_2(P_1/P_3)$	64	111.35	7.4	13.39	G
205	$F_2(P_1/P_3)$	72	103.53	7.9	12.31	G
206	$F_2(P_1/P_3)$	52	125.09	6.8	13.91	Bl
207	$F_2(P_1/P_3)$	84	107.53	8.3	11.39	Y
208	$F_2(P_1/P_3)$	64	114.49	7.9	12.83	Bl
209	$F_2(P_1/P_3)$	64	114.49	7.2	12.91	G
210	$F_2(P_1/P_3)$	88	103.43	8.8	11.19	G
211	$F_2(P_1/P_3)$	88	103.43	8.5	11.27	G
212	$F_2(P_1/P_3)$	56	131.65	6.4	13.91	G
213	$F_2(P_1/P_3)$	64	103.77	7.3	12.91	Bl
214	$F_2(P_1/P_3)$	88	98.09	9.1	11.35	Br
215	$F_2(P_1/P_3)$	68	115.09	7.4	12.35	Bl
216	$F_2(P_1/P_3)$	76	110.69	8.5	12.19	Y
217	$F_2(P_1/P_3)$	76	111.73	8.3	12.27	Y
218	$F_2(P_1/P_3)$	76	127.09	7.9	12.35	Bl
219	$F_2(P_1/P_3)$	76	107.11	7.6	12.35	Y
220	$F_2(P_1/P_3)$	64	133.04	7.2	13.29	Y
221	$F_2(P_1/P_3)$	76	115.09	7.9	12.35	Y

Appendix Table 2 (Continued)

Plant no.	Pedigree	Germination (%) (AA)	EC (µS/cm/g)	Seed coat (%)	100 seeds weight (g)	Seed coat color
222	$F_2(P_1/P_3)$	64	117.23	6.8	12.91	G
223	$F_2(P_1/P_3)$	64	119.25	7.2	13.29	Y
224	$F_2(P_1/P_3)$	64	119.25	7.4	12.91	G
225	$F_2(P_1/P_3)$	80	110.67	8.5	11.75	Bl
226	$F_2(P_1/P_3)$	76	111.31	8.1	12.23	Y
227	$F_2(P_1/P_3)$	64	110.59	7.4	13.07	Bl
228	$F_2(P_1/P_3)$	92	98.77	8.6	11.35	Y
229	$F_2(P_1/P_3)$	80	109.03	7.8	11.75	Y
230	$F_2(P_1/P_3)$	68	115.09	7.3	12.61	G
231	$F_2(P_1/P_3)$	52	128.10	7.2	13.89	Y
232	$F_2(P_1/P_3)$	52	124.09	7.2	13.89	G
233	$F_2(P_1/P_3)$	72	115.09	7.5	12.31	Bl
234	$F_2(P_1/P_3)$	36	131.78	6.0	15.67	G
235	$F_2(P_1/P_3)$	40	122.09	6.0	14.87	G
236	$F_2(P_1/P_3)$	52	121.32	7.3	13.77	G
237	$F_2(P_1/P_3)$	92	94.54	9.1	11.35	G
238	$F_2(P_1/P_3)$	92	94.54	9.2	11.35	Y
239	$F_2(P_1/P_3)$	84	107.62	8.2	11.75	Bl
240	$F_2(P_1/P_3)$	96	83.79	9.3	10.39	Bl
241	$F_2(P_1/P_3)$	80	111.43	7.8	11.91	G
242	$F_2(P_1/P_3)$	72	106.67	7.4	12.39	G
243	$F_2(P_1/P_3)$	80	120.00	7.6	11.75	Y
244	$F_2(P_1/P_3)$	48	128.34	6.4	14.19	G
245	$F_2(P_1/P_3)$	36	136.09	6.3	15.59	G
246	$F_2(P_1/P_3)$	60	117.97	7.9	12.79	G
247	$F_2(P_1/P_3)$	40	126.09	6.3	14.87	Y
248	$F_2(P_1/P_3)$	72	103.59	7.6	12.39	G
249	$F_2(P_1/P_3)$	80	105.84	8.2	11.87	Bl
250	$F_2(P_1/P_3)$	72	116.82	7.7	12.39	G
251	$F_2(P_1/P_3)$	52	138.09	6.7	13.95	Y
252	$F_2(P_1/P_3)$	36	134.09	6.3	15.59	G
253	$F_2(P_1/P_3)$	96	95.09	8.9	10.43	Bl
254	$F_2(P_1/P_3)$	44	142.03	6.3	14.39	G
255	$F_2(P_1/P_3)$	96	97.18	9.3	9.95	G
256	$F_2(P_1/P_3)$	68	100.44	7.3	12.61	Y
257	$F_2(P_1/P_3)$	96	97.97	8.9	9.67	Y
258	$F_2(P_1/P_3)$	48	119.97	6.5	14.19	Br
259	$F_2(P_1/P_3)$	72	103.83	7.2	12.43	G
260	$F_2(P_1/P_3)$	76	111.34	7.3	12.23	G
261	$F_2(P_1/P_3)$	96	93.13	8.5	11.19	Bl
262	$F_2(P_1/P_3)$	68	115.53	7.4	12.79	G
263	$F_2(P_1/P_3)$	60	118.97	6.7	13.31	Br
264	$F_2(P_1/P_3)$	80	106.99	7.5	11.99	G
265	$F_2(P_1/P_3)$	76	110.84	7.2	12.21	Y
266	$F_2(P_1/P_3)$	52	126.09	6.3	13.43	G

Appendix Table 2 (Continued)

Plant no.	Pedigree	Germination (%) (AA)	EC (µS/cm/g)	Seed coat (%)	100 seeds weight (g)	Seed coat color
267	$F_2(P_1/P_3)$	80	107.53	7.5	12.07	G
268	$F_2(P_1/P_3)$	80	107.53	7.5	12.07	G
269	$F_2(P_1/P_3)$	40	127.09	6.9	13.79	Y
270	$F_2(P_1/P_3)$	40	127.09	6.1	13.99	Bl
271	$F_2(P_1/P_3)$	64	114.96	6.8	12.91	G
272	$F_2(P_1/P_3)$	80	111.09	8.8	12.09	Bl
273	$F_2(P_1/P_3)$	68	105.28	7.5	12.79	G
274	$F_2(P_1/P_3)$	76	105.28	8.7	12.21	Bl
275	$F_2(P_1/P_3)$	64	116.53	6.4	12.91	G
276	$F_2(P_1/P_3)$	52	127.09	6.0	13.43	G
277	$F_2(P_1/P_3)$	88	103.59	8.8	11.83	G
278	$F_2(P_1/P_3)$	64	115.53	6.9	12.91	Bl
279	$F_2(P_1/P_3)$	96	100.24	9.2	9.87	G
280	$F_2(P_1/P_3)$	68	103.14	7.3	12.59	Bl
281	$F_2(P_1/P_3)$	64	103.14	6.4	12.91	G
282	$F_2(P_1/P_3)$	76	100.84	8.4	12.35	Bl
283	$F_2(P_1/P_3)$	68	103.59	7.9	12.59	G
284	$F_2(P_1/P_3)$	60	121.32	6.6	13.43	G
285	$F_2(P_1/P_3)$	36	139.83	5.2	14.95	Y
286	$F_2(P_1/P_3)$	72	108.59	7.8	12.35	G
287	$F_2(P_1/P_3)$	80	106.97	9.3	11.83	G
288	$F_2(P_1/P_3)$	72	106.97	7.6	12.35	G
289	$F_2(P_1/P_3)$	48	118.01	5.2	14.19	Y
290	$F_2(P_1/P_3)$	52	121.53	6.6	13.43	G
291	$F_2(P_1/P_3)$	44	124.09	5.2	14.39	G
292	$F_2(P_1/P_3)$	64	115.74	6.6	12.91	G
293	$F_2(P_1/P_3)$	72	102.55	7.3	12.35	G
294	$F_2(P_1/P_3)$	72	102.55	7.2	12.35	Y
295	$F_2(P_1/P_3)$	68	112.44	7.4	12.79	G
296	$F_2(P_1/P_3)$	44	132.88	5.7	14.19	Y
297	$F_2(P_1/P_3)$	64	117.97	6.7	12.91	G
298	$F_2(P_1/P_3)$	72	114.21	7.5	12.23	Br
299	$F_2(P_1/P_3)$	60	120.04	6.3	13.43	Bl
300	$F_2(P_1/P_3)$	72	111.53	7.9	12.23	Y
301	$F_2(P_1/P_3)$	68	115.53	7.9	12.35	G
302	$F_2(P_1/P_3)$	80	128.09	8.6	10.87	G
303	$F_2(P_1/P_3)$	64	119.97	6.7	12.91	G
304	$F_2(P_1/P_3)$	72	111.23	7.4	12.23	G
305	$F_2(P_1/P_3)$	60	117.97	6.7	13.39	G
306	$F_2(P_1/P_3)$	60	119.90	6.9	13.43	Br
307	$F_2(P_1/P_3)$	76	107.53	8.1	11.95	G
308	$F_2(P_1/P_3)$	76	126.09	7.6	11.95	G
309	$F_2(P_1/P_3)$	68	111.09	7.9	12.79	G
310	$F_2(P_1/P_3)$	60	118.59	5.9	13.39	G
311	$F_2(P_1/P_3)$	68	108.04	6.9	12.79	G

Appendix Table 2 (Continued)

Plant no.	Pedigree	Germination (%) (AA)	EC (µS/cm/g)	Seed coat (%)	100 seeds weight (g)	Seed coat color
312	$F_2(P_1/P_3)$	52	119.09	5.4	13.59	Br
313	$F_2(P_1/P_3)$	44	126.09	4.2	14.59	G
314	$F_2(P_1/P_3)$	96	89.96	9.3	11.75	Br
315	$F_2(P_1/P_3)$	76	103.63	7.5	11.95	G
316	$F_2(P_1/P_3)$	72	115.09	7.3	12.23	Br
317	$F_2(P_1/P_3)$	72	112.57	7.9	12.23	G
318	$F_2(P_1/P_3)$	48	124.09	4.8	14.19	G
319	$F_2(P_1/P_3)$	64	116.09	6.5	12.79	G
320	$F_2(P_1/P_3)$	96	99.53	8.4	11.75	G
321	$F_2(P_1/P_3)$	96	99.53	8.4	11.75	Bl
322	$F_2(P_1/P_3)$	60	126.09	7.1	13.39	G
323	$F_2(P_1/P_3)$	100	96.13	9.6	10.47	G
324	$F_2(P_1/P_3)$	100	96.91	9.6	9.59	Br
325	$F_2(P_1/P_3)$	100	96.59	8.9	10.87	G
326	$F_2(P_1/P_3)$	100	98.34	8.5	11.75	Br
327	$F_2(P_1/P_3)$	56	119.88	4.8	13.79	G
328	$F_2(P_1/P_3)$	60	125.09	6.9	13.39	Y
329	$F_2(P_1/P_3)$	84	95.09	7.7	11.95	G
330	$F_2(P_1/P_3)$	100	93.10	8.9	10.87	Bl
331	$F_2(P_1/P_3)$	44	127.09	6.4	14.19	Y
332	$F_2(P_1/P_3)$	60	110.53	7.2	13.47	Bl
333	$F_2(P_1/P_3)$	100	88.59	8.9	10.03	G
334	$F_2(P_1/P_3)$	40	139.75	6.0	14.03	G
335	$F_2(P_1/P_3)$	80	117.01	8.3	12.19	Y
336	$F_2(P_1/P_3)$	48	126.09	6.8	14.27	G
337	$F_2(P_1/P_3)$	48	124.09	6.8	14.27	G
338	$F_2(P_1/P_3)$	84	106.09	8.1	12.19	Br
339	$F_2(P_1/P_3)$	48	131.34	6.8	14.39	Y
340	$F_2(P_1/P_3)$	92	101.24	8.2	11.11	G
341	$F_2(P_1/P_3)$	52	120.33	6.9	13.67	Br
342	$F_2(P_1/P_3)$	76	111.57	7.9	12.59	G
343	$F_2(P_1/P_3)$	48	127.09	6.4	14.39	Y
344	$F_2(P_1/P_3)$	100	96.53	9.3	10.39	G
345	$F_2(P_1/P_3)$	60	118.59	7.6	13.39	Bl
346	$F_2(P_1/P_3)$	48	126.09	6.4	14.39	Br
347	$F_2(P_1/P_3)$	52	127.09	6.5	14.11	G
348	$F_2(P_1/P_3)$	52	125.09	6.5	14.11	Bl
349	$F_2(P_1/P_3)$	88	100.81	8.7	11.11	G
350	$F_2(P_1/P_3)$	60	121.11	7.9	12.83	G
351	$F_2(P_1/P_3)$	44	138.09	6.0	14.19	G
352	$F_2(P_1/P_3)$	52	121.53	6.5	14.11	Bl
353	$F_2(P_1/P_3)$	56	126.09	6.8	14.11	Bl
354	$F_2(P_1/P_3)$	92	100.83	8.7	10.71	G
355	$F_2(P_1/P_3)$	60	125.09	7.5	12.83	Br
356	$F_2(P_1/P_3)$	76	131.84	8.3	11.19	Y

Appendix Table 2 (Continued)

Plant no.	Pedigree	Germination (%) (AA)	EC (µS/cm/g)	Seed coat (%)	100 seeds weight (g)	Seed coat color
357	$F_2(P_1/P_3)$	76	131.84	8.4	11.47	G
358	$F_2(P_1/P_3)$	32	127.09	5.4	16.95	G
359	$F_2(P_1/P_3)$	68	113.65	7.7	12.35	G

Y = yellow, Bl = black, G = green, Br = brown

Appendix Table 3_ Some morpho-agronomic characters of parental varieties, F_1 hybrid and F_2 progenies of the soybean cross *CM60* x *GC10848*.

Plant no.	Pedigree	Hypo-cotyl color	Flower color	Stem termi-nation	Days to 50% flowering	Plant Height (cm)
1	CM60(P_1)	G	W	SD	33	32
2	CM60(P_1)	G	W	SD	34	32
3	CM60(P_1)	G	W	SD	32	27
4	CM60(P_1)	G	W	SD	33	26
5	CM60(P_1)	G	W	SD	33	27
6	CM60(P_1)	G	W	SD	32	36
7	CM60(P_1)	G	W	SD	33	35
8	CM60(P_1)	G	W	SD	32	35
9	CM60(P_1)	G	W	SD	33	32
10	CM60(P_1)	G	W	SD	32	35
11	CM60(P_1)	G	W	SD	31	37
12	CM60(P_1)	G	W	SD	32	35
13	CM60(P_1)	G	W	SD	31	34
14	CM60(P_1)	G	W	SD	32	36
15	CM60(P_1)	G	W	SD	32	38
16	CM60(P_1)	G	W	SD	33	32
17	CM60(P_1)	G	W	SD	32	27
18	CM60(P_1)	G	W	SD	33	35
19	CM60(P_1)	G	W	SD	34	37
20	CM60(P_1)	G	W	SD	34	37
21	CM60(P_1)	G	W	SD	33	37
22	CM60(P_1)	G	W	SD	32	38
23	CM60(P_1)	G	W	SD	31	36
24	CM60(P_1)	G	W	SD	32	37
25	CM60(P_1)	G	W	SD	31	35
26	CM60(P_1)	G	W	SD	32	39
27	CM60(P_1)	G	W	SD	33	39
28	CM60(P_1)	G	W	SD	32	38
29	CM60(P_1)	G	W	SD	33	38
30	CM60(P_1)	G	W	SD	32	39
1	GC10848(P_2)	P	P	D	25	9
2	GC10848(P_2)	P	P	D	25	8
3	GC10848(P_2)	P	P	D	26	9.5
4	GC10848(P_2)	P	P	D	26	8
5	GC10848(P_2)	P	P	D	26	8
6	GC10848(P_2)	P	P	D	25	9.5
7	GC10848(P_2)	P	P	D	26	9
8	GC10848(P_2)	P	P	D	25	10
9	GC10848(P_2)	P	P	D	25	9
10	GC10848(P_2)	P	P	D	26	8
11	GC10848(P_2)	P	P	D	26	6.5
12	GC10848(P_2)	P	P	D	25	7.5
13	GC10848(P_2)	P	P	D	25	8.5

Appendix Table 3 (Continued)

Plant no.	Pedigree	Hypo-cotyl color	Flower color	Stem termi-nation	Days to 50% flowering	Plant Height (cm)
14	GC10848(P_2)	P	P	D	25	9
15	GC10848(P_2)	P	P	D	26	8
16	GC10848(P_2)	P	P	D	26	10
17	GC10848(P_2)	P	P	D	25	10
18	GC10848(P_2)	P	P	D	26	8.5
19	GC10848(P_2)	P	P	D	25	7.5
20	GC10848(P_2)	P	P	D	26	7.5
21	GC10848(P_2)	P	P	D	26	10
22	GC10848(P_2)	P	P	D	25	10
23	GC10848(P_2)	P	P	D	25	8.5
24	GC10848(P_2)	P	P	D	26	10
25	GC10848(P_2)	P	P	D	26	8.5
26	GC10848(P_2)	P	P	D	27	11
27	GC10848(P_2)	P	P	D	26	7.5
28	GC10848(P_2)	P	P	D	25	8.5
29	GC10848(P_2)	P	P	D	25	7.5
30	GC10848(P_2)	P	P	D	26	7.5
1	$F_1(P_1/P_2)$	P	P	SD	30	17
2	$F_1(P_1/P_2)$	P	P	SD	30	16.5
3	$F_1(P_1/P_2)$	P	P	SD	31	17.5
4	$F_1(P_1/P_2)$	P	P	SD	29	15
5	$F_1(P_1/P_2)$	P	P	SD	30	16
6	$F_1(P_1/P_2)$	P	P	SD	31	17
7	$F_1(P_1/P_2)$	P	P	SD	29	14
8	$F_1(P_1/P_2)$	P	P	SD	29	15.5
9	$F_1(P_1/P_2)$	P	P	SD	30	16.5
10	$F_1(P_1/P_2)$	P	P	SD	29	17
1	$F_2(P_1/P_2)$	P	P	SD	30	23
2	$F_2(P_1/P_2)$	G	W	SD	30	23
3	$F_2(P_1/P_2)$	P	P	SD	27	15
4	$F_2(P_1/P_2)$	P	P	SD	29	23
5	$F_2(P_1/P_2)$	G	W	SD	30	25
6	$F_2(P_1/P_2)$	G	W	SD	30	27
7	$F_2(P_1/P_2)$	G	W	SD	31	23
8	$F_2(P_1/P_2)$	P	P	SD	31	22
9	$F_2(P_1/P_2)$	G	W	SD	31	24
10	$F_2(P_1/P_2)$	P	P	SD	27	16
11	$F_2(P_1/P_2)$	P	P	SD	27	15
12	$F_2(P_1/P_2)$	P	P	SD	29	18
13	$F_2(P_1/P_2)$	P	P	SD	29	18
14	$F_2(P_1/P_2)$	P	P	SD	31	20
15	$F_2(P_1/P_2)$	P	P	SD	32	32
16	$F_2(P_1/P_2)$	P	P	SD	32	33
17	$F_2(P_1/P_2)$	P	P	SD	31	34
18	$F_2(P_1/P_2)$	G	W	SD	32	23

Appendix Table 3 (Continued)

Plant no.	Pedigree	Hypo-cotyl color	Flower color	Stem termi-nation	Days to 50% flowering	Plant height (cm)
19	$F_2(P_1/P_2)$	P	P	SD	31	25
20	$F_2(P_1/P_2)$	P	P	SD	30	24
21	$F_2(P_1/P_2)$	G	W	SD	30	24
22	$F_2(P_1/P_2)$	P	P	SD	30	22
23	$F_2(P_1/P_2)$	P	P	SD	31	23
24	$F_2(P_1/P_2)$	P	P	D	27	9
25	$F_2(P_1/P_2)$	P	P	D	27	10
26	$F_2(P_1/P_2)$	P	P	SD	30	20
27	$F_2(P_1/P_2)$	P	P	SD	31	20
28	$F_2(P_1/P_2)$	G	W	SD	33	30
29	$F_2(P_1/P_2)$	G	W	D	27	14
30	$F_2(P_1/P_2)$	P	P	SD	32	24
31	$F_2(P_1/P_2)$	P	P	SD	31	20
32	$F_2(P_1/P_2)$	P	P	SD	29	19
33	$F_2(P_1/P_2)$	G	W	SD	27	16
34	$F_2(P_1/P_2)$	G	W	SD	27	16
35	$F_2(P_1/P_2)$	P	P	SD	31	44
36	$F_2(P_1/P_2)$	P	P	D	27	13
37	$F_2(P_1/P_2)$	P	P	SD	29	28
38	$F_2(P_1/P_2)$	P	P	SD	32	27
39	$F_2(P_1/P_2)$	P	P	SD	27	15
40	$F_2(P_1/P_2)$	P	P	SD	30	22
41	$F_2(P_1/P_2)$	P	P	D	27	14
42	$F_2(P_1/P_2)$	P	P	SD	27	15
43	$F_2(P_1/P_2)$	P	P	SD	30	27
44	$F_2(P_1/P_2)$	P	P	SD	30	29
45	$F_2(P_1/P_2)$	P	P	SD	27	15
46	$F_2(P_1/P_2)$	G	W	D	27	14
47	$F_2(P_1/P_2)$	P	P	D	27	12
48	$F_2(P_1/P_2)$	P	P	D	30	14
49	$F_2(P_1/P_2)$	P	P	SD	27	15
50	$F_2(P_1/P_2)$	G	W	SD	32	28
51	$F_2(P_1/P_2)$	P	P	SD	34	27
52	$F_2(P_1/P_2)$	P	P	SD	31	26
53	$F_2(P_1/P_2)$	P	P	SD	30	28
54	$F_2(P_1/P_2)$	G	W	SD	34	22
55	$F_2(P_1/P_2)$	P	P	SD	29	21
56	$F_2(P_1/P_2)$	P	P	SD	27	15
57	$F_2(P_1/P_2)$	P	P	D	27	11
58	$F_2(P_1/P_2)$	P	P	D	27	14
59	$F_2(P_1/P_2)$	G	W	D	27	14
60	$F_2(P_1/P_2)$	P	P	SD	30	19
61	$F_2(P_1/P_2)$	P	P	SD	32	38
62	$F_2(P_1/P_2)$	G	W	SD	29	18
63	$F_2(P_1/P_2)$	P	P	SD	27	16

Appendix Table 3 (Continued)

Plant no.	Pedigree	Hypo-cotyl color	Flower color	Stem termi-nation	Days to 50% flowering	Plant height (cm)
64	$F_2(P_1/P_2)$	P	P	D	27	11
65	$F_2(P_1/P_2)$	P	P	D	27	12
66	$F_2(P_1/P_2)$	P	P	SD	29	19
67	$F_2(P_1/P_2)$	G	W	SD	30	23
68	$F_2(P_1/P_2)$	P	P	SD	30	26
69	$F_2(P_1/P_2)$	P	P	D	27	12
70	$F_2(P_1/P_2)$	P	P	D	27	13
71	$F_2(P_1/P_2)$	G	W	D	27	13
72	$F_2(P_1/P_2)$	G	W	SD	29	21
73	$F_2(P_1/P_2)$	P	P	SD	29	24
74	$F_2(P_1/P_2)$	G	W	SD	32	25
75	$F_2(P_1/P_2)$	G	W	SD	31	22
76	$F_2(P_1/P_2)$	P	P	SD	31	21
77	$F_2(P_1/P_2)$	P	P	SD	31	20
78	$F_2(P_1/P_2)$	G	W	SD	32	22
79	$F_2(P_1/P_2)$	P	P	SD	27	16
80	$F_2(P_1/P_2)$	P	P	SD	32	23
81	$F_2(P_1/P_2)$	P	P	SD	29	19
82	$F_2(P_1/P_2)$	G	W	SD	30	20
83	$F_2(P_1/P_2)$	P	P	SD	29	18
84	$F_2(P_1/P_2)$	P	P	SD	29	18
85	$F_2(P_1/P_2)$	P	P	SD	32	25
86	$F_2(P_1/P_2)$	P	P	SD	27	16
87	$F_2(P_1/P_2)$	P	P	SD	29	19
88	$F_2(P_1/P_2)$	P	P	SD	34	25
89	$F_2(P_1/P_2)$	G	W	SD	32	26
90	$F_2(P_1/P_2)$	P	P	SD	27	15
91	$F_2(P_1/P_2)$	P	P	D	27	14
92	$F_2(P_1/P_2)$	P	P	SD	34	20
93	$F_2(P_1/P_2)$	P	P	SD	29	18
94	$F_2(P_1/P_2)$	P	P	D	27	13
95	$F_2(P_1/P_2)$	P	P	SD	32	20
96	$F_2(P_1/P_2)$	P	P	SD	34	21
97	$F_2(P_1/P_2)$	P	P	SD	27	15
98	$F_2(P_1/P_2)$	P	P	SD	27	15
99	$F_2(P_1/P_2)$	P	P	SD	29	19
100	$F_2(P_1/P_2)$	P	P	SD	29	18
101	$F_2(P_1/P_2)$	P	P	SD	32	24
102	$F_2(P_1/P_2)$	G	W	SD	30	25
103	$F_2(P_1/P_2)$	P	P	SD	29	19
104	$F_2(P_1/P_2)$	P	P	D	27	14
105	$F_2(P_1/P_2)$	P	P	SD	27	15
106	$F_2(P_1/P_2)$	P	P	D	27	13
107	$F_2(P_1/P_2)$	P	P	SD	29	18
108	$F_2(P_1/P_2)$	P	P	D	27	14

Appendix Table 3 (Continued)

Plant no.	Pedigree	Hypo-cotyl color	Flower color	Stem termi-nation	Days to 50% flowering	Plant height (cm)
109	$F_2(P_1/P_2)$	P	P	SD	27	16
110	$F_2(P_1/P_2)$	G	W	SD	34	38
111	$F_2(P_1/P_2)$	P	P	SD	27	16
112	$F_2(P_1/P_2)$	G	W	SD	29	18
113	$F_2(P_1/P_2)$	G	W	D	27	13
114	$F_2(P_1/P_2)$	P	P	D	27	11
115	$F_2(P_1/P_2)$	P	P	D	27	14
116	$F_2(P_1/P_2)$	P	P	SD	27	15
117	$F_2(P_1/P_2)$	G	W	SD	33	23
118	$F_2(P_1/P_2)$	P	P	D	27	13
119	$F_2(P_1/P_2)$	P	P	SD	29	18
120	$F_2(P_1/P_2)$	P	P	D	27	10
121	$F_2(P_1/P_2)$	P	P	SD	27	16
122	$F_2(P_1/P_2)$	P	P	SD	29	19
123	$F_2(P_1/P_2)$	P	P	D	27	9
124	$F_2(P_1/P_2)$	P	P	SD	29	19
125	$F_2(P_1/P_2)$	P	P	SD	32	27
126	$F_2(P_1/P_2)$	P	P	SD	29	18
127	$F_2(P_1/P_2)$	P	P	SD	31	24
128	$F_2(P_1/P_2)$	P	P	SD	32	27
129	$F_2(P_1/P_2)$	P	P	SD	32	33
130	$F_2(P_1/P_2)$	P	P	D	27	13
131	$F_2(P_1/P_2)$	G	W	SD	30	25
132	$F_2(P_1/P_2)$	P	P	D	27	14
133	$F_2(P_1/P_2)$	P	P	SD	27	16
134	$F_2(P_1/P_2)$	P	P	D	27	14
135	$F_2(P_1/P_2)$	P	P	SD	30	22
136	$F_2(P_1/P_2)$	P	P	SD	33	33
137	$F_2(P_1/P_2)$	P	P	D	27	12
138	$F_2(P_1/P_2)$	P	P	D	27	13
139	$F_2(P_1/P_2)$	P	P	SD	34	27
140	$F_2(P_1/P_2)$	G	W	D	27	10
141	$F_2(P_1/P_2)$	P	P	SD	33	25
142	$F_2(P_1/P_2)$	P	P	SD	32	34
143	$F_2(P_1/P_2)$	P	P	SD	33	23
144	$F_2(P_1/P_2)$	P	P	SD	33	23
145	$F_2(P_1/P_2)$	P	P	D	27	10
146	$F_2(P_1/P_2)$	G	W	SD	32	25
147	$F_2(P_1/P_2)$	P	P	D	26	13
148	$F_2(P_1/P_2)$	P	P	SD	32	24
149	$F_2(P_1/P_2)$	P	P	SD	29	23
150	$F_2(P_1/P_2)$	P	P	SD	29	19
151	$F_2(P_1/P_2)$	P	P	SD	29	19
152	$F_2(P_1/P_2)$	P	P	SD	29	18
153	$F_2(P_1/P_2)$	G	W	SD	27	16

Appendix Table 3 (Continued)

Plant no.	Pedigree	Hypo-cotyl color	Flower color	Stem termi-nation	Days to 50% flowering	Plant height (cm)
154	$F_2(P_1/P_2)$	P	P	SD	32	31
155	$F_2(P_1/P_2)$	P	P	SD	32	28
156	$F_2(P_1/P_2)$	P	P	SD	29	19
157	$F_2(P_1/P_2)$	P	P	D	27	13
158	$F_2(P_1/P_2)$	P	P	D	27	13
159	$F_2(P_1/P_2)$	P	P	D	27	13
160	$F_2(P_1/P_2)$	G	W	SD	29	18
161	$F_2(P_1/P_2)$	G	W	SD	29	18
162	$F_2(P_1/P_2)$	G	W	D	27	9
163	$F_2(P_1/P_2)$	P	P	SD	32	22
164	$F_2(P_1/P_2)$	P	P	SD	29	19
165	$F_2(P_1/P_2)$	P	P	D	27	11
166	$F_2(P_1/P_2)$	G	W	SD	34	35
167	$F_2(P_1/P_2)$	P	P	D	27	13
168	$F_2(P_1/P_2)$	P	P	SD	29	19
169	$F_2(P_1/P_2)$	P	P	SD	35	24
170	$F_2(P_1/P_2)$	P	P	SD	27	16
171	$F_2(P_1/P_2)$	P	P	SD	27	15
172	$F_2(P_1/P_2)$	P	P	D	27	13
173	$F_2(P_1/P_2)$	P	P	SD	34	28
174	$F_2(P_1/P_2)$	P	P	SD	32	28
175	$F_2(P_1/P_2)$	P	P	SD	29	18
176	$F_2(P_1/P_2)$	G	W	SD	29	18
177	$F_2(P_1/P_2)$	P	P	SD	31	29
178	$F_2(P_1/P_2)$	G	W	SD	29	27
179	$F_2(P_1/P_2)$	P	P	SD	34	25
180	$F_2(P_1/P_2)$	P	P	SD	27	16
181	$F_2(P_1/P_2)$	G	W	SD	29	19
182	$F_2(P_1/P_2)$	G	W	SD	33	22
183	$F_2(P_1/P_2)$	P	P	D	27	14
184	$F_2(P_1/P_2)$	P	P	D	27	13
185	$F_2(P_1/P_2)$	P	P	SD	27	15
186	$F_2(P_1/P_2)$	P	P	SD	33	21
187	$F_2(P_1/P_2)$	G	W	D	27	11
188	$F_2(P_1/P_2)$	P	P	SD	29	20
189	$F_2(P_1/P_2)$	G	W	SD	29	31
190	$F_2(P_1/P_2)$	P	P	SD	35	29
191	$F_2(P_1/P_2)$	P	P	SD	29	18
192	$F_2(P_1/P_2)$	P	P	SD	29	18
193	$F_2(P_1/P_2)$	P	P	SD	34	23
194	$F_2(P_1/P_2)$	P	P	SD	29	20
195	$F_2(P_1/P_2)$	P	P	SD	27	16
196	$F_2(P_1/P_2)$	P	P	D	27	9
197	$F_2(P_1/P_2)$	P	P	D	27	14
198	$F_2(P_1/P_2)$	G	W	D	27	13

Appendix Table 3 (Continued)

Plant no.	Pedigree	Hypo-cotyl color	Flower color	Stem termi-nation	Days to 50% flowering	Plant height (cm)
199	$F_2(P_1/P_2)$	G	W	SD	27	15
200	$F_2(P_1/P_2)$	G	W	SD	32	28
201	$F_2(P_1/P_2)$	P	P	D	27	14
202	$F_2(P_1/P_2)$	G	W	SD	33	24
203	$F_2(P_1/P_2)$	P	P	SD	31	26
204	$F_2(P_1/P_2)$	P	P	D	27	14
205	$F_2(P_1/P_2)$	G	W	D	27	10
206	$F_2(P_1/P_2)$	P	P	SD	33	25
207	$F_2(P_1/P_2)$	P	P	D	27	14
208	$F_2(P_1/P_2)$	G	W	SD	31	23
209	$F_2(P_1/P_2)$	G	W	SD	29	18
210	$F_2(P_1/P_2)$	P	P	D	27	14
211	$F_2(P_1/P_2)$	P	P	SD	27	15
212	$F_2(P_1/P_2)$	P	P	SD	29	19
213	$F_2(P_1/P_2)$	P	P	SD	32	30
214	$F_2(P_1/P_2)$	P	P	SD	27	15
215	$F_2(P_1/P_2)$	G	W	SD	35	30
216	$F_2(P_1/P_2)$	P	P	D	27	14
217	$F_2(P_1/P_2)$	P	P	D	27	10
218	$F_2(P_1/P_2)$	G	W	SD	31	23
219	$F_2(P_1/P_2)$	P	P	SD	29	19
220	$F_2(P_1/P_2)$	P	P	SD	31	20
221	$F_2(P_1/P_2)$	P	P	D	27	13
222	$F_2(P_1/P_2)$	P	P	SD	27	16
223	$F_2(P_1/P_2)$	G	W	SD	27	16
224	$F_2(P_1/P_2)$	G	W	D	26	12
225	$F_2(P_1/P_2)$	P	P	SD	26	15
226	$F_2(P_1/P_2)$	G	W	D	27	14
227	$F_2(P_1/P_2)$	P	P	SD	29	18
228	$F_2(P_1/P_2)$	G	W	SD	30	35
229	$F_2(P_1/P_2)$	P	P	SD	27	16
230	$F_2(P_1/P_2)$	P	P	SD	33	29
231	$F_2(P_1/P_2)$	G	W	D	27	12
232	$F_2(P_1/P_2)$	P	P	D	27	11
233	$F_2(P_1/P_2)$	P	P	D	27	12
234	$F_2(P_1/P_2)$	P	P	D	27	14
235	$F_2(P_1/P_2)$	P	P	SD	35	25
236	$F_2(P_1/P_2)$	P	P	SD	34	27
237	$F_2(P_1/P_2)$	P	P	SD	34	28
238	$F_2(P_1/P_2)$	G	W	SD	35	22
239	$F_2(P_1/P_2)$	P	P	D	27	14

G = green, P = purple, W = white, SD = semi-determinate, D = determinate

Appendix Table 4 Some morpho-agronomic characters of parental varieties, F_1 hybrid and F_2 progenies of the soybean cross *CM60* x *Kalitur*.

Plant no.	Pedigree	Hypo-cotyl color	Flower color	Stem termi-nation	Days to 50% flowering	Plant height (cm)
1	CM60(P_1)	G	W	SD	33	32
2	CM60(P_1)	G	W	SD	34	32
3	CM60(P_1)	G	W	SD	32	27
4	CM60(P_1)	G	W	SD	33	26
5	CM60(P_1)	G	W	SD	33	27
6	CM60(P_1)	G	W	SD	32	36
7	CM60(P_1)	G	W	SD	33	35
8	CM60(P_1)	G	W	SD	32	35
9	CM60(P_1)	G	W	SD	33	32
10	CM60(P_1)	G	W	SD	32	35
11	CM60(P_1)	G	W	SD	31	37
12	CM60(P_1)	G	W	SD	32	35
13	CM60(P_1)	G	W	SD	31	34
14	CM60(P_1)	G	W	SD	32	36
15	CM60(P_1)	G	W	SD	32	38
16	CM60(P_1)	G	W	SD	33	32
17	CM60(P_1)	G	W	SD	32	27
18	CM60(P_1)	G	W	SD	33	35
19	CM60(P_1)	G	W	SD	34	37
20	CM60(P_1)	G	W	SD	34	37
21	CM60(P_1)	G	W	SD	33	37
22	CM60(P_1)	G	W	SD	32	38
23	CM60(P_1)	G	W	SD	31	36
24	CM60(P_1)	G	W	SD	32	37
25	CM60(P_1)	G	W	SD	31	35
26	CM60(P_1)	G	W	SD	32	39
27	CM60(P_1)	G	W	SD	33	39
28	CM60(P_1)	G	W	SD	32	38
29	CM60(P_1)	G	W	SD	33	38
30	CM60(P_1)	G	W	SD	32	39
1	Kalitur(P_3)	P	P	I	37	67
2	Kalitur(P_3)	P	P	I	38	56
3	Kalitur(P_3)	P	P	I	37	58
4	Kalitur(P_3)	P	P	I	38	50
5	Kalitur(P_3)	P	P	I	38	52
6	Kalitur(P_3)	P	P	I	38	54
7	Kalitur(P_3)	P	P	I	37	56
8	Kalitur(P_3)	P	P	I	37	63
9	Kalitur(P_3)	P	P	I	38	52
10	Kalitur(P_3)	P	P	I	37	51
11	Kalitur(P_3)	P	P	I	37	56
12	Kalitur(P_3)	P	P	I	38	57
13	Kalitur(P_3)	P	P	I	38	51

Appendix Table 4 (continued)

Plant no.	Pedigree	Hypo-cotyl color	Flower color	Stem termi-nation	Days to 50% flowering	Plant height (cm)
14	Kalitur(P_3)	P	P	I	37	64
15	Kalitur(P_3)	P	P	I	38	66
16	Kalitur(P_3)	P	P	I	37	53
17	Kalitur(P_3)	P	P	I	38	65
18	Kalitur(P_3)	P	P	I	38	55
19	Kalitur(P_3)	P	P	I	37	67
20	Kalitur(P_3)	P	P	I	38	51
21	Kalitur(P_3)	P	P	I	38	78
22	Kalitur(P_3)	P	P	I	37	67
23	Kalitur(P_3)	P	P	I	37	75
24	Kalitur(P_3)	P	P	I	38	56
25	Kalitur(P_3)	P	P	I	38	68
26	Kalitur(P_3)	P	P	I	36	77
27	Kalitur(P_3)	P	P	I	37	61
28	Kalitur(P_3)	P	P	I	37	60
29	Kalitur(P_3)	P	P	I	36	66
30	Kalitur(P_3)	P	P	I	37	70
1	$F_1(P_1/P_3)$	P	P	SD	35	40
2	$F_1(P_1/P_3)$	P	P	SD	35	46
3	$F_1(P_1/P_3)$	P	P	SD	35	46
4	$F_1(P_1/P_3)$	P	P	SD	36	46
5	$F_1(P_1/P_3)$	P	P	SD	35	39
6	$F_1(P_1/P_3)$	P	P	SD	35	40
7	$F_1(P_1/P_3)$	P	P	SD	36	37
8	$F_1(P_1/P_3)$	P	P	SD	36	37
9	$F_1(P_1/P_3)$	P	P	SD	35	39
10	$F_1(P_1/P_3)$	P	P	SD	35	40
11	$F_1(P_1/P_3)$	P	P	SD	35	41
12	$F_1(P_1/P_3)$	P	P	SD	35	47
13	$F_1(P_1/P_3)$	P	P	SD	35	46
14	$F_1(P_1/P_3)$	P	P	SD	36	41
15	$F_1(P_1/P_3)$	P	P	SD	36	40
16	$F_1(P_1/P_3)$	P	P	SD	35	51
17	$F_1(P_1/P_3)$	P	P	SD	36	45
18	$F_1(P_1/P_3)$	P	P	SD	36	48
19	$F_1(P_1/P_3)$	P	P	SD	36	40
20	$F_1(P_1/P_3)$	P	P	SD	35	39
21	$F_1(P_1/P_3)$	P	P	SD	35	38
22	$F_1(P_1/P_3)$	P	P	SD	35	39
23	$F_1(P_1/P_3)$	P	P	SD	35	45
24	$F_1(P_1/P_3)$	P	P	SD	35	39
25	$F_1(P_1/P_3)$	P	P	SD	36	40
26	$F_1(P_1/P_3)$	P	P	SD	36	36
27	$F_1(P_1/P_3)$	P	P	SD	36	40
28	$F_1(P_1/P_3)$	P	P	SD	36	38

Appendix Table 4 (continued)

Plant no.	Pedigree	Hypo-cotyl color	Flower color	Stem termi-nation	Days to 50% flowering	Plant height (cm)
29	$F_1(P_1/P_3)$	P	P	SD	39	41
30	$F_1(P_1/P_3)$	P	P	SD	35	42
1	$F_2(P_1/P_3)$	P	P	SD	36	44
2	$F_2(P_1/P_3)$	P	P	I	38	55
3	$F_2(P_1/P_3)$	P	P	SD	36	45
4	$F_2(P_1/P_3)$	P	P	SD	35	34
5	$F_2(P_1/P_3)$	P	P	SD	35	34
6	$F_2(P_1/P_3)$	P	P	SD	35	37
7	$F_2(P_1/P_3)$	P	P	SD	34	28
8	$F_2(P_1/P_3)$	P	P	SD	36	43
9	$F_2(P_1/P_3)$	P	P	SD	37	47
10	$F_2(P_1/P_3)$	P	P	I	37	57
11	$F_2(P_1/P_3)$	P	P	SD	35	34
12	$F_2(P_1/P_3)$	P	P	SD	34	33
13	$F_2(P_1/P_3)$	P	P	SD	36	45
14	$F_2(P_1/P_3)$	G	W	SD	29	37
15	$F_2(P_1/P_3)$	P	P	I	37	56
16	$F_2(P_1/P_3)$	P	P	SD	34	35
17	$F_2(P_1/P_3)$	P	P	I	37	57
18	$F_2(P_1/P_3)$	P	P	SD	34	27
19	$F_2(P_1/P_3)$	P	P	SD	36	43
20	$F_2(P_1/P_3)$	G	W	SD	37	48
21	$F_2(P_1/P_3)$	G	W	SD	34	43
22	$F_2(P_1/P_3)$	P	P	SD	37	47
23	$F_2(P_1/P_3)$	G	W	SD	35	25
24	$F_2(P_1/P_3)$	G	W	SD	34	24
25	$F_2(P_1/P_3)$	G	W	SD	33	28
26	$F_2(P_1/P_3)$	P	P	I	38	58
27	$F_2(P_1/P_3)$	G	W	SD	37	47
28	$F_2(P_1/P_3)$	P	P	I	38	64
29	$F_2(P_1/P_3)$	P	P	I	38	57
30	$F_2(P_1/P_3)$	P	P	SD	36	44
31	$F_2(P_1/P_3)$	P	P	SD	34	32
32	$F_2(P_1/P_3)$	P	P	I	38	55
33	$F_2(P_1/P_3)$	P	P	I	38	64
34	$F_2(P_1/P_3)$	P	P	I	38	58
35	$F_2(P_1/P_3)$	P	P	SD	34	24
36	$F_2(P_1/P_3)$	P	P	SD	34	24
37	$F_2(P_1/P_3)$	G	W	SD	33	33
38	$F_2(P_1/P_3)$	P	P	SD	34	35
39	$F_2(P_1/P_3)$	G	W	SD	35	42
40	$F_2(P_1/P_3)$	P	P	I	39	58
41	$F_2(P_1/P_3)$	P	P	SD	34	38
42	$F_2(P_1/P_3)$	P	P	I	38	54
43	$F_2(P_1/P_3)$	P	P	I	39	62

Appendix Table 4 (continued)

Plant no.	Pedigree	Hypo-cotyl color	Flower color	Stem termi-nation	Days to 50% flowering	Plant height (cm)
44	$F_2(P_1/P_3)$	P	P	I	40	54
45	$F_2(P_1/P_3)$	P	P	I	39	67
46	$F_2(P_1/P_3)$	P	P	I	39	58
47	$F_2(P_1/P_3)$	G	W	SD	34	44
48	$F_2(P_1/P_3)$	P	P	I	37	54
49	$F_2(P_1/P_3)$	G	W	SD	35	42
50	$F_2(P_1/P_3)$	P	P	SD	34	35
51	$F_2(P_1/P_3)$	P	P	SD	36	45
52	$F_2(P_1/P_3)$	P	P	SD	40	52
53	$F_2(P_1/P_3)$	P	P	SD	37	48
54	$F_2(P_1/P_3)$	P	P	I	38	54
55	$F_2(P_1/P_3)$	P	P	SD	36	44
56	$F_2(P_1/P_3)$	G	W	SD	35	40
57	$F_2(P_1/P_3)$	G	W	SD	37	48
58	$F_2(P_1/P_3)$	P	P	SD	34	42
59	$F_2(P_1/P_3)$	P	P	SD	37	48
60	$F_2(P_1/P_3)$	P	P	SD	34	33
61	$F_2(P_1/P_3)$	P	P	I	38	65
62	$F_2(P_1/P_3)$	P	P	SD	34	32
63	$F_2(P_1/P_3)$	G	W	SD	40	48
64	$F_2(P_1/P_3)$	P	P	SD	34	28
65	$F_2(P_1/P_3)$	P	P	SD	36	44
66	$F_2(P_1/P_3)$	P	P	I	38	63
67	$F_2(P_1/P_3)$	P	P	SD	32	33
68	$F_2(P_1/P_3)$	P	P	SD	34	23
69	$F_2(P_1/P_3)$	G	W	SD	34	34
70	$F_2(P_1/P_3)$	P	P	SD	34	34
71	$F_2(P_1/P_3)$	P	P	SD	35	42
72	$F_2(P_1/P_3)$	P	P	SD	36	43
73	$F_2(P_1/P_3)$	P	P	SD	36	43
74	$F_2(P_1/P_3)$	P	P	SD	34	28
75	$F_2(P_1/P_3)$	P	P	SD	38	43
76	$F_2(P_1/P_3)$	G	W	SD	31	44
77	$F_2(P_1/P_3)$	G	W	SD	35	38
78	$F_2(P_1/P_3)$	P	P	SD	35	41
79	$F_2(P_1/P_3)$	G	W	SD	34	32
80	$F_2(P_1/P_3)$	P	P	SD	33	29
81	$F_2(P_1/P_3)$	P	P	SD	35	41
82	$F_2(P_1/P_3)$	G	W	SD	35	29
83	$F_2(P_1/P_3)$	P	P	SD	34	27
84	$F_2(P_1/P_3)$	G	W	SD	33	24
85	$F_2(P_1/P_3)$	P	P	SD	34	37
86	$F_2(P_1/P_3)$	P	P	SD	36	45
87	$F_2(P_1/P_3)$	P	P	SD	37	48
88	$F_2(P_1/P_3)$	G	W	SD	37	47

Appendix Table 4 (continued)

Plant no.	Pedigree	Hypo-cotyl color	Flower color	Stem termi-nation	Days to 50% flowering	Plant height (cm)
89	$F_2(P_1/P_3)$	P	P	SD	33	33
90	$F_2(P_1/P_3)$	P	P	SD	34	38
91	$F_2(P_1/P_3)$	G	W	SD	36	44
92	$F_2(P_1/P_3)$	G	W	SD	36	44
93	$F_2(P_1/P_3)$	P	P	SD	38	48
94	$F_2(P_1/P_3)$	G	W	SD	34	33
95	$F_2(P_1/P_3)$	G	W	SD	34	32
96	$F_2(P_1/P_3)$	P	P	SD	35	42
97	$F_2(P_1/P_3)$	P	P	SD	38	48
98	$F_2(P_1/P_3)$	P	P	SD	32	28
99	$F_2(P_1/P_3)$	P	P	SD	32	32
100	$F_2(P_1/P_3)$	G	W	SD	34	45
101	$F_2(P_1/P_3)$	P	P	SD	34	43
102	$F_2(P_1/P_3)$	P	P	SD	37	47
103	$F_2(P_1/P_3)$	P	P	SD	36	43
104	$F_2(P_1/P_3)$	G	W	SD	37	48
105	$F_2(P_1/P_3)$	P	P	SD	38	48
106	$F_2(P_1/P_3)$	P	P	I	37	55
107	$F_2(P_1/P_3)$	P	P	SD	34	34
108	$F_2(P_1/P_3)$	P	P	SD	35	37
109	$F_2(P_1/P_3)$	P	P	SD	34	43
110	$F_2(P_1/P_3)$	G	W	SD	33	38
111	$F_2(P_1/P_3)$	G	W	SD	37	50
112	$F_2(P_1/P_3)$	P	P	I	38	55
113	$F_2(P_1/P_3)$	P	P	SD	39	49
114	$F_2(P_1/P_3)$	P	P	SD	33	43
115	$F_2(P_1/P_3)$	P	P	SD	35	34
116	$F_2(P_1/P_3)$	G	W	SD	36	44
117	$F_2(P_1/P_3)$	P	P	SD	37	49
118	$F_2(P_1/P_3)$	P	P	SD	34	27
119	$F_2(P_1/P_3)$	P	P	SD	33	30
120	$F_2(P_1/P_3)$	P	P	SD	35	33
121	$F_2(P_1/P_3)$	P	P	I	39	55
122	$F_2(P_1/P_3)$	P	P	I	40	68
123	$F_2(P_1/P_3)$	P	P	SD	33	43
124	$F_2(P_1/P_3)$	G	W	SD	32	18
125	$F_2(P_1/P_3)$	P	P	SD	34	42
126	$F_2(P_1/P_3)$	G	W	SD	35	42
127	$F_2(P_1/P_3)$	P	P	SD	34	33
128	$F_2(P_1/P_3)$	P	P	SD	31	18
129	$F_2(P_1/P_3)$	G	W	SD	34	43
130	$F_2(P_1/P_3)$	P	P	SD	34	38
131	$F_2(P_1/P_3)$	G	W	SD	34	43
132	$F_2(P_1/P_3)$	P	P	I	37	55
133	$F_2(P_1/P_3)$	P	P	I	37	55

Appendix Table 4 (continued)

Plant no.	Pedigree	Hypo-cotyl color	Flower color	Stem termi-nation	Days to 50% flowering	Plant height (cm)
134	$F_2(P_1/P_3)$	G	W	SD	34	32
135	$F_2(P_1/P_3)$	G	W	SD	36	45
136	$F_2(P_1/P_3)$	P	P	SD	36	45
137	$F_2(P_1/P_3)$	P	P	SD	36	48
138	$F_2(P_1/P_3)$	P	P	SD	36	43
139	$F_2(P_1/P_3)$	P	P	SD	36	43
140	$F_2(P_1/P_3)$	G	W	SD	33	33
141	$F_2(P_1/P_3)$	P	P	SD	32	24
142	$F_2(P_1/P_3)$	G	W	SD	40	49
143	$F_2(P_1/P_3)$	G	W	SD	33	38
144	$F_2(P_1/P_3)$	P	P	SD	34	43
145	$F_2(P_1/P_3)$	G	W	SD	34	33
146	$F_2(P_1/P_3)$	P	P	SD	32	33
147	$F_2(P_1/P_3)$	P	P	SD	39	50
148	$F_2(P_1/P_3)$	P	P	SD	37	48
149	$F_2(P_1/P_3)$	P	P	SD	34	25
150	$F_2(P_1/P_3)$	G	W	SD	34	25
151	$F_2(P_1/P_3)$	P	P	SD	35	25
152	$F_2(P_1/P_3)$	P	P	SD	40	52
153	$F_2(P_1/P_3)$	P	P	SD	36	43
154	$F_2(P_1/P_3)$	P	P	SD	34	39
155	$F_2(P_1/P_3)$	P	P	SD	40	49
156	$F_2(P_1/P_3)$	P	P	SD	36	43
157	$F_2(P_1/P_3)$	G	W	SD	34	33
158	$F_2(P_1/P_3)$	P	P	I	39	63
159	$F_2(P_1/P_3)$	P	P	SD	39	48
160	$F_2(P_1/P_3)$	G	W	SD	36	44
161	$F_2(P_1/P_3)$	P	P	SD	34	39
162	$F_2(P_1/P_3)$	P	P	SD	40	53
163	$F_2(P_1/P_3)$	P	P	SD	40	53
164	$F_2(P_1/P_3)$	P	P	I	40	56
165	$F_2(P_1/P_3)$	G	W	SD	34	34
166	$F_2(P_1/P_3)$	P	P	SD	34	35
167	$F_2(P_1/P_3)$	G	W	SD	39	50
168	$F_2(P_1/P_3)$	P	P	I	40	60
169	$F_2(P_1/P_3)$	P	P	I	40	58
170	$F_2(P_1/P_3)$	P	P	I	39	58
171	$F_2(P_1/P_3)$	P	P	SD	36	43
172	$F_2(P_1/P_3)$	P	P	SD	29	28
173	$F_2(P_1/P_3)$	P	P	I	37	54
174	$F_2(P_1/P_3)$	P	P	SD	37	53
175	$F_2(P_1/P_3)$	P	P	SD	36	44
176	$F_2(P_1/P_3)$	G	W	I	39	54
177	$F_2(P_1/P_3)$	P	P	I	39	54
178	$F_2(P_1/P_3)$	P	P	SD	36	44

Appendix Table 4 (continued)

Plant no.	Pedigree	Hypo-cotyl color	Flower color	Stem termi-nation	Days to 50% flowering	Plant height (cm)
179	$F_2(P_1/P_3)$	P	P	SD	37	48
180	$F_2(P_1/P_3)$	P	P	SD	34	45
181	$F_2(P_1/P_3)$	P	P	SD	35	39
182	$F_2(P_1/P_3)$	G	W	SD	36	45
183	$F_2(P_1/P_3)$	P	P	I	40	76
184	$F_2(P_1/P_3)$	P	P	I	44	63
185	$F_2(P_1/P_3)$	P	P	I	40	63
186	$F_2(P_1/P_3)$	P	P	SD	36	43
187	$F_2(P_1/P_3)$	P	P	SD	34	27
188	$F_2(P_1/P_3)$	P	P	SD	32	28
189	$F_2(P_1/P_3)$	G	W	SD	34	29
190	$F_2(P_1/P_3)$	P	P	SD	34	37
191	$F_2(P_1/P_3)$	P	P	I	40	65
192	$F_2(P_1/P_3)$	P	P	I	40	68
193	$F_2(P_1/P_3)$	P	P	I	40	66
194	$F_2(P_1/P_3)$	P	P	I	39	60
195	$F_2(P_1/P_3)$	P	P	I	40	73
196	$F_2(P_1/P_3)$	P	P	I	40	73
197	$F_2(P_1/P_3)$	P	P	SD	36	44
198	$F_2(P_1/P_3)$	G	W	SD	35	42
199	$F_2(P_1/P_3)$	G	W	SD	39	53
200	$F_2(P_1/P_3)$	G	W	SD	35	39
201	$F_2(P_1/P_3)$	P	P	SD	36	44
202	$F_2(P_1/P_3)$	P	P	SD	39	53
203	$F_2(P_1/P_3)$	P	P	I	39	54
204	$F_2(P_1/P_3)$	G	W	SD	37	48
205	$F_2(P_1/P_3)$	P	P	I	40	78
206	$F_2(P_1/P_3)$	P	P	I	39	80
207	$F_2(P_1/P_3)$	P	P	I	39	67
208	$F_2(P_1/P_3)$	P	P	SD	34	20
209	$F_2(P_1/P_3)$	P	P	SD	36	43
210	$F_2(P_1/P_3)$	P	P	SD	36	43
211	$F_2(P_1/P_3)$	G	W	SD	32	20
212	$F_2(P_1/P_3)$	G	W	SD	39	50
213	$F_2(P_1/P_3)$	G	W	SD	37	47
214	$F_2(P_1/P_3)$	P	P	SD	34	28
215	$F_2(P_1/P_3)$	P	P	SD	34	33
216	$F_2(P_1/P_3)$	P	P	SD	37	47
217	$F_2(P_1/P_3)$	P	P	SD	36	44
218	$F_2(P_1/P_3)$	P	P	I	38	61
219	$F_2(P_1/P_3)$	P	P	I	38	58
220	$F_2(P_1/P_3)$	P	P	SD	32	29
221	$F_2(P_1/P_3)$	P	P	I	39	68
222	$F_2(P_1/P_3)$	P	P	I	38	62
223	$F_2(P_1/P_3)$	P	P	I	39	63

Appendix Table 4 (continued)

Plant no.	Pedigree	Hypo-cotyl color	Flower color	Stem termi-nation	Days to 50% flowering	Plant height (cm)
224	$F_2(P_1/P_3)$	P	P	SD	37	49
225	$F_2(P_1/P_3)$	P	P	SD	36	43
226	$F_2(P_1/P_3)$	G	W	SD	38	48
227	$F_2(P_1/P_3)$	G	W	SD	38	48
228	$F_2(P_1/P_3)$	P	P	SD	35	40
229	$F_2(P_1/P_3)$	P	P	SD	35	40
230	$F_2(P_1/P_3)$	P	P	SD	36	43
231	$F_2(P_1/P_3)$	P	P	SD	34	43
232	$F_2(P_1/P_3)$	P	P	SD	34	43
233	$F_2(P_1/P_3)$	G	W	SD	37	47
234	$F_2(P_1/P_3)$	P	P	SD	35	37
235	$F_2(P_1/P_3)$	G	W	SD	34	37
236	$F_2(P_1/P_3)$	P	P	SD	35	23
237	$F_2(P_1/P_3)$	G	W	SD	37	53
238	$F_2(P_1/P_3)$	P	P	SD	37	53
239	$F_2(P_1/P_3)$	P	P	I	39	62
240	$F_2(P_1/P_3)$	P	P	I	37	53
241	$F_2(P_1/P_3)$	P	P	I	37	53
242	$F_2(P_1/P_3)$	P	P	I	38	63
243	$F_2(P_1/P_3)$	G	W	SD	34	38
244	$F_2(P_1/P_3)$	P	P	I	37	53
245	$F_2(P_1/P_3)$	P	P	SD	35	38
246	$F_2(P_1/P_3)$	P	P	SD	37	47
247	$F_2(P_1/P_3)$	P	P	I	38	74
248	$F_2(P_1/P_3)$	P	P	SD	35	23
249	$F_2(P_1/P_3)$	P	P	SD	34	30
250	$F_2(P_1/P_3)$	G	W	SD	32	44
251	$F_2(P_1/P_3)$	P	P	SD	33	44
252	$F_2(P_1/P_3)$	P	P	SD	32	37
253	$F_2(P_1/P_3)$	P	P	I	39	64
254	$F_2(P_1/P_3)$	P	P	I	39	62
255	$F_2(P_1/P_3)$	P	P	I	39	53
256	$F_2(P_1/P_3)$	G	W	SD	39	52
257	$F_2(P_1/P_3)$	P	P	SD	35	42
258	$F_2(P_1/P_3)$	P	P	SD	35	40
259	$F_2(P_1/P_3)$	G	W	I	42	58
260	$F_2(P_1/P_3)$	P	P	SD	34	32
261	$F_2(P_1/P_3)$	P	P	SD	37	48
262	$F_2(P_1/P_3)$	P	P	I	38	54
263	$F_2(P_1/P_3)$	P	P	I	38	64
264	$F_2(P_1/P_3)$	G	W	I	38	59
265	$F_2(P_1/P_3)$	P	P	I	37	54
266	$F_2(P_1/P_3)$	P	P	SD	37	48
267	$F_2(P_1/P_3)$	P	P	SD	38	48
268	$F_2(P_1/P_3)$	P	P	I	39	58

Appendix Table 4 (continued)

Plant no.	Pedigree	Hypo-cotyl color	Flower color	Stem termi-nation	Days to 50% flowering	Plant height (cm)
269	$F_2(P_1/P_3)$	P	P	I	39	59
270	$F_2(P_1/P_3)$	P	P	SD	35	39
271	$F_2(P_1/P_3)$	P	P	SD	36	45
272	$F_2(P_1/P_3)$	G	W	SD	34	33
273	$F_2(P_1/P_3)$	P	P	I	39	68
274	$F_2(P_1/P_3)$	G	W	SD	38	52
275	$F_2(P_1/P_3)$	P	P	I	38	64
276	$F_2(P_1/P_3)$	P	P	I	39	64
277	$F_2(P_1/P_3)$	P	P	I	37	53
278	$F_2(P_1/P_3)$	G	W	I	37	53
279	$F_2(P_1/P_3)$	P	P	SD	33	44
280	$F_2(P_1/P_3)$	G	W	SD	34	43
281	$F_2(P_1/P_3)$	P	P	SD	38	49
282	$F_2(P_1/P_3)$	P	P	SD	37	49
283	$F_2(P_1/P_3)$	G	W	SD	37	49
284	$F_2(P_1/P_3)$	G	W	SD	34	30
285	$F_2(P_1/P_3)$	G	W	SD	34	30
286	$F_2(P_1/P_3)$	G	W	I	37	53
287	$F_2(P_1/P_3)$	P	P	I	40	53
288	$F_2(P_1/P_3)$	G	W	SD	36	45
289	$F_2(P_1/P_3)$	P	P	SD	37	48
290	$F_2(P_1/P_3)$	P	P	SD	37	48
291	$F_2(P_1/P_3)$	P	P	SD	39	48
292	$F_2(P_1/P_3)$	G	W	SD	35	32
293	$F_2(P_1/P_3)$	P	P	SD	35	33
294	$F_2(P_1/P_3)$	P	P	SD	34	33
295	$F_2(P_1/P_3)$	P	P	SD	32	30
296	$F_2(P_1/P_3)$	P	P	SD	35	33
297	$F_2(P_1/P_3)$	P	P	SD	34	20
298	$F_2(P_1/P_3)$	P	P	SD	34	20
299	$F_2(P_1/P_3)$	P	P	SD	35	23
300	$F_2(P_1/P_3)$	P	P	SD	35	38
301	$F_2(P_1/P_3)$	P	P	SD	35	38
302	$F_2(P_1/P_3)$	P	P	SD	39	49
303	$F_2(P_1/P_3)$	G	W	SD	35	23
304	$F_2(P_1/P_3)$	P	P	SD	32	38
305	$F_2(P_1/P_3)$	P	P	SD	34	24
306	$F_2(P_1/P_3)$	G	W	SD	32	28
307	$F_2(P_1/P_3)$	G	W	SD	36	43
308	$F_2(P_1/P_3)$	P	P	SD	35	38
309	$F_2(P_1/P_3)$	P	P	SD	34	23
310	$F_2(P_1/P_3)$	P	P	SD	36	44
311	$F_2(P_1/P_3)$	P	P	SD	36	45
312	$F_2(P_1/P_3)$	P	P	SD	36	43
313	$F_2(P_1/P_3)$	P	P	SD	32	18

Appendix Table 4 (continued)

Plant no.	Pedigree	Hypo-cotyl color	Flower color	Stem termi-nation	Days to 50% flowering	Plant height (cm)
314	$F_2(P_1/P_3)$	P	P	SD	35	38
315	$F_2(P_1/P_3)$	P	P	SD	35	38
316	$F_2(P_1/P_3)$	P	P	SD	37	50
317	$F_2(P_1/P_3)$	P	P	SD	36	44
318	$F_2(P_1/P_3)$	G	W	SD	34	43
319	$F_2(P_1/P_3)$	P	P	SD	34	42
320	$F_2(P_1/P_3)$	G	W	SD	33	42
321	$F_2(P_1/P_3)$	P	P	SD	39	52
322	$F_2(P_1/P_3)$	P	P	SD	33	27
323	$F_2(P_1/P_3)$	G	W	SD	35	32
324	$F_2(P_1/P_3)$	P	P	I	39	53
325	$F_2(P_1/P_3)$	G	W	SD	32	23
326	$F_2(P_1/P_3)$	P	P	SD	34	43
327	$F_2(P_1/P_3)$	G	W	SD	37	48
328	$F_2(P_1/P_3)$	P	P	SD	35	37
329	$F_2(P_1/P_3)$	G	W	SD	35	43
330	$F_2(P_1/P_3)$	G	W	I	40	55
331	$F_2(P_1/P_3)$	P	P	SD	34	28
332	$F_2(P_1/P_3)$	P	P	SD	34	23
333	$F_2(P_1/P_3)$	G	W	SD	33	23
334	$F_2(P_1/P_3)$	P	P	I	49	61
335	$F_2(P_1/P_3)$	P	P	I	41	58
336	$F_2(P_1/P_3)$	P	P	I	46	73
337	$F_2(P_1/P_3)$	P	P	I	43	53
338	$F_2(P_1/P_3)$	G	W	SD	44	48
339	$F_2(P_1/P_3)$	P	P	SD	42	50
340	$F_2(P_1/P_3)$	G	W	SD	35	42
341	$F_2(P_1/P_3)$	P	P	I	43	62
342	$F_2(P_1/P_3)$	P	P	SD	40	48
343	$F_2(P_1/P_3)$	P	P	SD	34	40
344	$F_2(P_1/P_3)$	P	P	I	49	54
345	$F_2(P_1/P_3)$	P	P	I	40	63
346	$F_2(P_1/P_3)$	P	P	SD	38	52
347	$F_2(P_1/P_3)$	G	W	I	49	55
348	$F_2(P_1/P_3)$	P	P	I	41	65
349	$F_2(P_1/P_3)$	P	P	SD	36	45
350	$F_2(P_1/P_3)$	P	P	I	44	53
351	$F_2(P_1/P_3)$	P	P	I	41	54
352	$F_2(P_1/P_3)$	P	P	SD	34	38
353	$F_2(P_1/P_3)$	P	P	SD	36	45
354	$F_2(P_1/P_3)$	G	W	SD	35	42
355	$F_2(P_1/P_3)$	P	P	I	37	53
356	$F_2(P_1/P_3)$	G	W	SD	33	38
357	$F_2(P_1/P_3)$	P	P	SD	33	32
358	$F_2(P_1/P_3)$	P	P	SD	40	49

Appendix Table 4 (continued)

Plant no.	Pedigree	Hypo-cotyl color	Flower color	Stem termi-nation	Days to 50% flowering	Plant height (cm)
359	$F_2(P_1/P_3)$	P	P	SD	39	52

G = green, P = purple, W = white, SD = semi-determinate, I = indeterminate

CURRICULUM VITAE

NAME	Mr. Myint Soe
BIRTH DATE	January 19, 1961
BIRTH PLACE	Myingyan, Union of Myanmar
EDUCATION	B.Agr.Sc. (1984) Yezin Agricultural University
POSITION/TITLE	Assistant Research Officer
WORK PLACE	Department of Agricultural Research Yezin, Union of Myanmar
SCHOLARSHIP/AWARD	Oil Crops Development Project Ministry of Agriculture and Irrigation, Union of Myanmar