MIXING ABILITY AND INTERGENOTYPIC COMPETITION FROM 7X7 UNIBLENDS AND BIBLENDS OF MUNGBEAN (*Vigna radiata* L,Wilckzek.) GENOTYPES

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CERTIFICATE

This is to certify that thesis entitled, **“MIXING ABILITY AND INTERGENOTYPIC COMPETITION FROM 7X7 UNIBLENDS AND BIBLENDS OF MUNGBEAN (***Vigna radiata* L,Wilckzek.**) GENOTYPES ”** submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE in GENETICS AND PLANT BREEDING**, embodies the result of a piece of bona fide research work carried out by **MD. ASHRAFUL ALAM**, Registration No. 03-01180 under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

I further certify that such help or source of information, as has been availed of during the course of this investigation has duly been acknowledged.

Dated: June, 2009
Place: Dhaka, Bangladesh

……………………………………………………………
(Dr. Md. Shahidur Rashid Bhuiyan)
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Dedicated to

My

Beloved Parents

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SYMBOLS AND ABBREVIATIONS USED

% = Percent
$^{o}{}_{C}$ = Degree Celsius
AEZ = Agro-ecological Zone
AFLP = Amplified Fragment Length Polymorphism
ANOVA, anova = Analysis of Variance
BA = Boric Acid
BARI = Bangladesh Agricultural Research Institute
BAU = Bangladesh Agricultural University
BBS = Bangladesh Beauro of Statistics
BP = Better-parent
BR = Blend Response
CASR = Committee for Advance Studies and Research
cm = Centimeter, Centimetre
COP = Coefficient of Parentage
CO_2 = Carbon di-oxide
DAS = Days After Sowing
d.f. = Degree of Freedom
DLA = Diseased Leaf Area
FAO = Food and Agriculture Organization
Fig. = Figure
G = Gram
GBA = General Blending Ability
GMA, gma = General Mixing Ability
GYA = General Yielding Ability
Ha = Hectare
Kg = Kilogram
LER = Land Equivalent Ratio
M = Meter
Me = Mean Square due to Error
MG = Maturity Group
Mg = Mean Square due to gma

MP = Muriate of Potash
MP = Mid-parent
Ms = Mean Square due to sma
MS = Mean Square
MYMV = Mungbean Yellow Mosaic Virus
RAPD = Random Amplified Polymorphic DNA
RCBD = randomized completely block design
Rep. = Replication
SAU = Sher-e-Bangla Agricultural University
SCA = Specific Competing Ability
SE = Standard Error
SMA, sma = Specific Mixing Ability
SRDI = Soil Resource and Development Institute
SV = Standard Variety
TGCA = True General Competitive Ability
TSP = Triple Super Phosphate
USA = United States of America
YUD = Yield Under Disease
< = Greater than
< = Smaller than

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ABSTRACTS

ABSTRACTS

Cultivar mixtures have been suggested as a means to achieve increased crop productivity. By choosing cultivars that complement each other for performance of important traits, mixtures could be formulated to meet specific production requirements. Mixing ability and inter-genotypic competition from 7x7 mechanical diallel mixtures excluding reciprocals of Mungbean (*Vigna radiata* (1.) Wilczek.) were studied, during March to Mid June 2008, under two experimental sets which provided for intra-row and inter row mixing of genotypes in biblend, designated respectively as Set I and set II, as well as uniblend stand in both Sets. The significant differences among the genotypes were found for all the traits examined. Seven mungbean uniblend line and the 21 biblends obtained by mixing seed of pairs of cultivars in equal proportions were evaluated. The mean performance analysis showed that, the genotype BD-6893 showed best performance for most of the vitally important characters such as pods per plant, seeds/plant, and yield/plant. In respect of biblend mixture, the biblend BD-6901+BD-6922 was found as best biblend mixture for different characters. Averaged biblends were 1.35% higher yielding than the mean yield of their uniblend components. For grain yield, performance in biblends was highly correlated with the average of the two component uniblends. The genotype BD-6906 had a good mixing ability for different yield and yield contributing characters as pods/plant, pod length, seeds/pod, yield/plant etc. in the both experimental sets. The mixture (biblend) BD-6901 + BD-6922, BD-6893+BD-6901 and BD-6921+BD-6922 were found to be a good specific mixer for different characters. Diallel analysis of mixing ability, analogous to genetic analysis of combining ability, demonstrated that uniblends differed in their ability to determine grain yield in biblends. The ability to predict biblend performance based on uniblend performance, together with the potential for above average grain yield, suggested that biblends can be formulated to achieve specific production requirements. Although varietal mixtures are not an alternative to pure culture, they nevertheless exhibit better performance under any adverse conditio

INTRODUCTION

CHAPTER I

INTRODUCTION

Pulses are important crops in Bangladesh. They occupy an area of about 0.47 million ha (>5% of the total cropped area) and contribute about 2% of the total grain production of the country (BBS, 2001). The major pulses grown in Bangladesh are: Khesari *(Lathyrus sativus* L.), Lentil (*Lens culinaris* Medic), Chickpea (*Cicer arietinum* L.), Blackgram (*Vigna mungo* L.), Mungbean (*Vigna radiata* L.) and Fieldpea (*Pisum sativum*). Among these khesari, lentil, chickpea and fieldpea are grown during winter (November-March) and contribute about 82% of total pulses. Mungbean is grown both in early summer (February-April) and in late summer.

Pulse crops belong to grain legume. It plays a vital role in national economy and in the diet. Pulses, a common item in the daily diet of the people of Bangladesh, are the edible seed of legumes. Pulses have been considered poor men's meat since they are the cheapest source of protein for the under privileged people who can not effort animal protein and it is taken mostly in the form of soup. Generally there is no complete dish without "dail" in this county. The green plants can also be used as animal feed and the residues as manure. It is the also best source of protein for domestic animals. Pluses contain a remarkable amount of minerals, vitamins, fats and carbohydrates. Pluses protein is rich in amino acids like isoleucine, leucine, lysine, valine etc. FAO (1999) recommends a minimum pluse intake of 80/head/day whereas; it is only 14.19 g in Bangladesh (BBS, 2006). This is because of fact that national production of the pulse is not adequate to meet for national demand. Both the acreage and production of the pulses are decreasing in Bangladesh day by day due to the inception of wheat and boro rice in our cropping system with irrigation facilities. At present, the area under pulse crop is 0.406 million ha with a production of 0.322 million ton (BBS, 2005), where mungbean is cultivated in the area of 0.108 million ha with production of 0.03 million ton (BBS, 2005). The average yield of mungbean is 0.69t/ha (BBS, 2005).

Mungbean originated in South Asia (India, Burma, Thailand etc.). Now it is widely grown in India, Pakistan, Bangladesh, Burma, Thailand, Philippines, China and Indonesia. It is also grown in parts of east and central Africa, The West Indies, USA and Australia (Gowda and Kaul, 1982).

The mungbean (*Vigna radiata* (L.) Wilczek) is an important crop in our country. It is also referred to as green gram, golden gram and chop soy bean. Among the pulse crop, mungbean has a special importance in intensive crop production system of the country for its short growing period (Ahmed et al, 1978). The crop is potentially useful in improving cropping system as it can be grown as a catch crop due to its rapid growth and early maturing characteristics. It can also fix atmospheric nitrogen through the symbiotic relationship between the lost mungbean roots and soil bacteria and thus improve soil fertility.

Mungbean is one of the important pulse crops in the country for its high digestibility, good flavor and high protein content. It holds the first position in price, 3rd in protein content and 4the in both acreage and production in Bangladesh (Anonymous, 1999; Sarker et al., 1982). Hence from the point of nutritional value, mungbean is perhaps the best of all other pulses (Khan et Al, 1982). It contents 51% carbohydrate, 26% proteins, 3% mineral and 3% vitamin (Kaul, 1982).

Mungbean (*Vigna radiata* L.) is sub-tropical, kharif crops, well adapted to semi arid and sub-humid zones with annual rainfall between 600-1000 mm. requiring an optimum mean temperature of 30°C. It grows successfully on sandy loam to clay loam soil. Usually grown on low to medium elevations in the tropics as a rain-feed crop (Andeshna *et al.,* 1993). Expantion of mungbean cultiation in such non traditional areas depends largely on its competive ability with other crops (Hamid, 1996) as well as its adaptability over a wide range of environmental conditions (Popalghat *et al*., 2001). Among the environmental factors, excess rain at the time of reproductive period causes enormous loss of both seed yield and seed quality of mungbean (Williams *et al*., 1995).

In Bangladesh it can grown in late winter and summer season. Summer mungbean can tolerate a high temperature exceeding 40^0C and grows well in the temperature range of 30-35^0C. There are evidences in India; mungbean gives higher yields under summer planting than winter season (Sing & Yadav, 1978). The crop is also reported to be drought tolerant and can also be cultivated in areas of low rainfall, but also grows well in areas with 750-900 mm (Kay, 1979).

Various morphophysiological characters contribute to the seed yield of mungbean and it is a complex characters. These yield contributing characters are related among themselves showing a complex chain of relationship on yield. The effectiveness of increasing yield depends on the extent to which the variability of yield is dependent on genetic factors (Julfiquar, 1977). Since many of the quantitative plant characters which are of economic value, are highly influenced by environmental condition; the progress of breeding in such a population are primarily conditioned by the magnitude and nature of variation and interrelationship of plant characters (Gandhi et al., 1964). The magnitude of heritable variability is clearly the most important aspect in crop improvement.

Practice of unilateral selection for characters frequently end up in retrograde of less than optimum results in plant breeding (Bhatt, 1973). Conventional breeding techniques such as pure line and pedigree selection have served the purpose to an extent. Synthesis of appropriate heterogeneous populations (blends) could open up new avenues in efforts to improve yield stability. As a result of using mixing ability and population buffering, mixtures could prove more beneficial than componenets alone.

Varietal mixtures are common in subsistence farming systems, offering growers diversity of diet, stability of income, and reduced losses to pests (Smithson and Lennè, 1996). Most research on cultivar mixtures has focused on mixing component cultivars that differ in their disease resistance to manage foliar pathogens (Jeger et al., 1981; Stuke and Fehrmann, 1988; Finckh and Wolfe, 1997). When intraspecific diversity of disease resistance is deployed in a given field, there is a tendency for disease incidence and yield to match that of the most resistant component (Finckh and Wolfe, 1997). The genetic diversity of varietal mixtures may also contribute to higher grain yield in the absence of pests. Gustafsson (1953) examined three barley (*Hordeum vulgare* L.) cultivars and all possible two-way mixtures under a range of fertility and spacing treatments. Mixtures were found to be superior to the average of the two variety components in every situation, with an average yield advantage of about 4%. Furthermore, one component cultivar was identified that caused the mixture to exceed the highest yielding component of that mixture.

Sage (1971) studied the yield of mixtures obtained by blending seed of cultivars in equal proportions. Yields of mixtures were higher than those of pure lines only at low seeding rates, and it was concluded that the advantage of mixtures would only be realized in unfavorable environments. There is some evidence that high-yielding mixtures must have a high-yielding component. Working with oat mixtures, Pfahler (1965) found that yield stability was improved in mixtures relative to the pure line components. The yield benefit realized with mixtures may be a function of greater niche exploitation or complementary resource utilization, mechanisms which have been studied in great depth in interspecific mixtures, e.g., intercropping systems (Fukai and Trenbath, 1993), but not, to our knowledge, in intraspecific mixtures. Therefore, mixture performance could be influenced by numerous site-specific conditions including fertility, precipitation, seeding dates and rates, as well as possibly weed pressure.

A lot of research have been done to increase the present yield of grain legumes including mungbean . But so far, no breakthrough has occurred in the yield ceiling of these crops. Researches have shown that as a result of using mixing ability and population buffering, mixtures could prove more beneficial than components alone (Mahmud, 2002). In a mixing ability analysis in lentil in 7x7 mechanical diallel mixtures excluding reciprocals, the researcher's opinion is that although varietal mixtures are not an alternative to pure culture, they nevertheless exhibit better performance under stress conditions (Shukla and Singh, 1999).

Analyses of general mixing ability (GMA) and specific mixing ability (SMA) assume importance as prerequisites embarking on a sound crop- improvement program through genotypic mixtures. So far, in Bangladesh, no intensive work has been reported on the improvement of yield of mungbean with particular reference to mixing ability and inter-genotypic competition.

However, the information on the mixing ability and inter-genotypic competition their relationships with the information with the major yield components in mungbean are scarce.

Objectives

With this aim in view of the above discussion, an experiment was conducted with the following objectives-

- To study the mixing ability effects of selected genotypes on yield and component characters.
- To characterize inter-genotypic competition and its effects on various quantitative characters.
- To identify desirable genotypes for synthesizing promising genotypes mixtures.
- To isolate the best mixture in relation to yield.

REVIEW OF LITERATURE

CHAPTER II

REVIEW OF LITERATURE

Mungbean is an important pulse crop of global economic importance. Extensive research work on this crop has been done in several countries, especially in the South East Asia for the improvement of its yield and quality. In Bangladesh little attention has so far been given for the improvement of mungbean and blackgram. Recently Bangladesh Agricultural Research Institute and Bangladesh Institute of Nuclear Agriculture have started research on varietal development and various agronomic management of the crop.

Very few information was available regarding the effect uniblend and biblend of mungbean on the seed yield and its quality. Although this idea was not a recent one but research findings in this regard was scanty. Some of the pertinent works on these technologies reviewed in this chapter.

2.1. Mixing Ability

Schutz and Brim (1971) analyzed yield data from for soybean (*Glycine max* (L.) Merrill) varieties, six two-component mixtures, and four three-component mixtures to compare the effect of inter-genotypic competition on population stability. Yield tests were conducted in three-row plots at four locations in each of four years. Stability was measured by estimating the relative contributions of pure lines and mixtures to the first and second order interactions of entries, locations, and years; by constructing frequency distributions of rank order; and by regression and deviations from regression of population performance on environmental productivity. Mixtures were generally more stable than the pure lines, with the degree of stability apparently dependent upon the type of competitive interaction involved.

Erskine (1977) observed six lines and four mixtures of cowpea in six environments throughout lowland Papua New Guinea. There were no significant transgress increases in the grain yield of mixtures above their pure line components, and mixture yields were adequately predicted by the mean of components. In yield stability it was found that the individual buffering of purelines was of more importance than population buffering, and that the magnitude of population buffering varied with the particular combination of components. Competitive effects in all the mixtures were of the compensating type. Dramatic changes in mixture composition resulting from natural selection precluded their use in local agriculture. The out come of competition in mixtres was strongly influenced by the growing environment.

Luedders (1979) observed the effect of maturity on competitive ability in two cultivars of soybeans (*Glycine max* (L.) Merr.). Maturity dates within a genotype were simulated by removing half the plants from pure stands at end of flowering and twice later at approximately intervals. Simulation of the early maturity of an equal competetitor gave a significant competitive advantage to the late genotype only 2 out of 15 times. The average effect from simulation of earlier maturity within the genotype was statistically significant, but small, especially since the assumed difference in competitive ability probably were due to characteristics other than maturity.

Federer et al. (1982) employed response model equation and corresponding statistical analyses for experiments involving mixtures of pairs of cultivars (biblends), both when the individual yields in a biblend and when only the total yields are available. These weree applied to yield data for eight dry bean (*Phaseolus vulgaris* L.) cultivars. Concepts of general mixing and specific mixing effects were discussed in relation to the convepts of general and specific combining ability in diallel crossing experiments. In diallel crossing experiments, only the total to the two components is available, whereas in the bean experiments as referred by Frederer and co-workers, individual yields of the two cultivars in a biblend were available.

Shukla and Singh (1999) studied a set of 21 mechanical diallel varietal mixtures involving seven parental components of lentil to assess their extent of superiority over better-parent (BP), mid-parent (MP) and standard variety (SV) for yield and yield contributing characters. The maximum magnitudes of superiority over BP, MP, and SV for seed yield/plant were observed to be 18.5%, 26.4% and 30.6% respectively, in Pant Lentil 234 + Lentil Hisar 84-8 mixtures. Mixtures that showed superiority for seed yield/plant were not superior for all the characters.

Shukla and Singh (1999) investigated mixing ability in lentil (*Lens culinaris* Medik.) in 7x7 mechanical diallel mixtures excluding reciprocals. Variances due to general mixing ability (GMA) and specific mixing ability (SMA) were highly significant for all the characters except days to maturity and seeds pod-1 in the case of GMA and 100-seed weight in the case of SMA. Parent Lentil Hisar 84-8 was found to be a good gereral mixture for most of the characters. Although vrietal mixtures are not an alternative to pure culture, they nevertheless exhibit better performance under stress conditions.

Mahmud (2002) studied mixing ability and inter-genotypic competition from 7x7 mechanical diallel mixtures excluding reciprocals of Soybean (*Glycine max* L.) under two experimental sets which provided for intra-row and inter-row mixing of genotypes in biblend, designated respectively as Set I and Set II, as well as uniblend stand in both. The mean performance analysis showed that, the genotype G-2 showed the best performance for pods/plant, seeds/plant, yield/plant, biological yield/plant and yield/plot. The genotype BS-16 was found to be a good general mixer for plant height, branches/plant, yield/plant, biological yield/plant and yield/plot in both the experimental sets. The genotype G-2 had a good mixing ability for pods/plant, seeds/5-pods and seeds/plant in both experimental sets. The plant mixture BS-3+BS-16 was found to be a good specific mixer for plant height, branches/plant, pods/plant, seeds/plant, yield/plant, biological yield/plant, and yield/plot in experimental Set-I. But in experimental Set-II, the mixture PB-1+Bs-16 was found to be a good mixer for branches/plant, pods/plant, seeds/5-pods, seeds/plant, yield/plant, biological yield/plant, yield/plot and 100-seed weight.

Mahmud et al. (2006) studied mixing ability in lentil (*Lens culinaris* Medik.) in 5x5 mechanical diallel mixtures excluding reciprocals. Variances due to general mixing ability (GMA) and specific mixing ability (SMA) were significant for all the characters except plant height and plant spread in cse of SMA and primary branches/plant and biological yield/plant in both the cases. Parent BARI masur-4 was found to be a good general mixer for most of the characters, viz., yield/plant, seeds/plant, plant spread, harvest index, pods/plant and secondary branches/plant.the biblend BARImasur-1+BINAmasur-1 was foundto be a good specific mixer for days to maturity, yield/plant, seeds/plant, plant spread, harvest index, pods/plant and secondary branches/plant. The performance of biblend BARImasur-3+ BINAmasur-1 was the same for seed yield along with harvest index, 1000-seeed weight, seeds/plant, pods/plant, primary branches/plant and days to maturity. Although varietal mixtures are not an alternative to pure culture, they nevertheless exhibit better performance under any adverse condition.

Helland and Holland (2001) stated that genetic diversity in cropping systems can provide buffering against varying environmental conditions. Therefore, cultivar blends may have greater and more stable yields than their pure-line components. Optimization of cultivar blend development requires knowledge of the relative importance of pure-line yield potential, blend response, and cultivar interactions to blend yield. Grain yield and volume weight of oat (*Avena sativa* L.) pure-line cultivars and cultivar blends were measured in eight Iowa environments in order to compare their productivity and stability and to estimate genetic components of blend yields. In one experiment, five early-maturing cultivars were grown as pure lines and as all possible two- and three-way cultivar blends. In a second experiment, ten midseason-maturing cultivars were grown as pure lines and as all possible two-way blends. Grain yield was 3% greater ($P < 0.05$) and volume weight was 1% greater ($P < 0.05$) in blends than in pure lines in the early-maturity experiment; however, pure line and blends did not differ in the midseason-maturity experiment. Blends had more stable ($P < 0.05$) yields than pure lines in the early-maturity experiment only. Modified diallel analysis was used to partition the variation among two-way blends into general yielding ability (GYA) and true general competitive ability (TGCA) of each component genotype, and specific competing ability (SCA) interaction between blend components. General yielding ability variation was significant, whereas variation for neither TGCA nor SCA was significant. Oat genotype responses to blending were sufficiently consistent across blending partners that superior blends can be selected based on pure-line evaluations of early-maturing cultivars

Baker and Briggs (1984) evaluated pure strands (uniblends) of 10 cultivars of spring barley (*Hordeum vulgare* L.) and the 45 possible 50:50 mixtures (biblends) for 3 years in four-replicate randomized blocks. In addition to plot grain yield, data were collected on grain weight, shoot weight, and harvest index from 20 plants (10 in 1977) sampled from each uniblend and from 10 plants of each of the components of each of the biblends. Single plant sampling was carried out in only two replicates in each year. Cultivar identification in the biblend samples was facilitated by evaluation of spike and seed characteristics of each plant. Analyses of whole plot yield and of single plant data indicated that there were no significant differences between average performances in uniblends and biblends. Absence of significant interaction implied that relative cultivar performance in uniblends and biblends was the same. These results suggest that intergenotypic competition among relatively well adapted genotypes should not be of serious consequence in barley breeding programs.

Gallandt et al. (2001) noted that cultivar mixtures have been suggested as a means to achieve increased crop productivity. By choosing cultivars that complement each other for performance of important traits, mixtures could be formulated to meet specific production requirements. The objective of this study was to evaluate the performance of wheat mixtures and their pure line component cultivars across a wide range of environmental conditions. Six winter wheat (*Triticum aestivum* L.) pure line cultivars and the 15 mixtures obtained by mixing seed of pairs of cultivars in equal proportions were evaluated in 33 environments in eastern Washington. Averaged across all environments, mixtures were 1.5% higher yielding than the mean yield of their pure line cultivar components. There was no difference in protein between mixtures and pure line cultivars. For both grain yield and protein, performance in mixtures was highly correlated with the average of the two component pure lines. Diallel analysis of mixing ability, analogous to genetic analysis of combining ability, demonstrated that pure lines differed in their ability to determine both grain yield and protein in mixtures. The ability to predict mixture performance based on pure line performance, together with the potential for above average grain yield, suggested that mixtures can be formulated to achieve specific production requirements.

Trimble and Fehr (1983) found that seed mixtures of soybean [*Glycine max* (L.) Merr.] Cultivars are an alternative to a pure stand of a high-yielding susceptible or a lower-yielding resistant cultivar for minimizing yield loss from iron-deficiency chlorosis. Our objective was to determine the relationship between the yield of mixtures and the frequency of component cultivars that differ in their level of resistance to iron-deficiency chlorosis. Seed of a highly resistant line A2 was mixed with each of four cultivars; 'Weber' (moderately resistant), 'Wells' (moderately susceptible), 'Corsoy' (susceptible), and 'S1492' (highly susceptible). The proportions varied by 10% increments from 90% A2 to 10% A2. The nine mixtures of each cultivar pair and a pure stand of each component were evaluated in Iowa on calcareous soil in replicated yield tests at seven environments. The cultivar pair x component frequency interaction was highly significant because the yield of the mixtures varied with the amount of yield reduction sustained by the susceptible component. There were no significant differences in yield among frequencies for the A2-Weber mixtures at any of the seven environments. The results indicate that there would not be a benefit from mixing a high-yielding cultivar with moderate resistance and a lower-yielding cultivar with a high level of resistance. The average percentage of A2 required in a mixture to obtain a yield within 10% of a pure stand of A2 was 20% for A2-Wells, 33% for A2-Corsoy, and 39% for A2-S1492. Productivity of fields planted to a seed mixture, resistant cultivar, or susceptible cultivar depends on the percentage of calcareous area in the field, the yield difference between the resistant and susceptible cultivars on noncalcareous soil, and the level of chlorosis susceptibility for the cultivars being considered. Procedures are discussed for calculating when a cultivar or a mixture would be most productive.

Carter et al. (1989) had undertaken this study to evaluate a practical method that describes the relative worth of genotypes in blend combination. Eight adapted soybean [*Glycine max* (L.) Merr.] genotypes and all two-way blend combinations were evaluated in eight environments in North Carolina during 1983 to 1985. Genetic effects were partitioned through diallel analysis of two variables: blend yield per se and blend response (BR), the deviation of blend yield from the pure line component average. General blending ability (GBA) and its components, true general competitive ability (TGCA), and general yielding ability (GYA) are defined and related to existing terminology to describe the worth of a genotype as a blend component. General blending ability, statistically analogous to general combining ability, is obtained from diallel analysis of blend yield per se and reflects both the ability of a genotype to affect blend response through competition and its separate ability to yield in pure stand. The TGCA is obtained from diallel analysis of BR and reflects only that contribution of a blend component due to competitive effects. The GYA reflects only the innate yielding ability of a genotype in pure stand and is obtained as the difference between GBA and TGCA. Genotypes in this study differed significantly for GBA, TGCA, and GYA, while components analogous to specific combining ability were nonsignificant. The TGCA and GYA were found to be independent and equally important components of GBA, indicating that both effects must be considered in describing the relative worth of a genotype in blend performance. Results indicate that some genotypes consistently enhance blend performance through competition regardless of the partner genotype involved. This is a novel finding that has implications to the development of superior blends. The GBA, TGCA, and GYA taken together may be used in a practical way to identify desirable genotypes for blending.

Shorter and Frey (1979) evaluated relative yields of mixtures and monocultures of eight cultivars and 20 random F_9-derived oat (*Avena sativa* L.) lines from a bulk population at two locations for 2 years. Three diallel sets of two-component mixtures were constructed: 378 1:1 mixtures among 28 lines, as well as 105 1:3 mixtures among 15 lines (four cultivars and 11 random lines). The 28 oat lines also were mixed in a 1:1 frequency with each of six testers (homogeneous and heterogeneous at low, medium, and high grain yield levels) to identify lines forming high yielding mixtures. Results revealed that general mixing ability was significant ($P \leq 0.01$) for grain and straw yields and specific mixing ability was not. Of the 1:1 mixtures, 321 for grain yield and 305 for straw yield were not significantly different ($P \leq 0.05$) from their component means. Only 15 1:1 mixtures for grainyield and 10 for straw yield, significantly ($P \leq 0.05$) outyielded thexr higher yielding component (by to 11% for grain and 15% for straw). Cultivar mixtures exceeded their component means by up to 7% for grain or straw yield whereas random line mixtures were superior to their component means by up to 13% for grain yield and 17% for straw yield. Grain or straw yield differentials between mixtures and their components in monoculture generally had repeatability of 0 to 32% over environments. Seven (for grain) and five (for straw) mixtures out of 105 used in the component.frequency experiment had significant ($P \leq 0.05$) linear effects across component frequencies, and none had significant quadratic effects for either trait, indicating that mixture components interacted additively. Line performances in monoculture and in 1:1 mixtures were significantly correlated (r = 0.91 for both grain and strawyield (P $\leq$0.05). For both traits, the highest yielding mixtures were not superior to either their higheryieldin.g component or the fine with the highest monoculture y~eld. Therefore, use of mixtures of oat cultivars or lines to obtain a yield advantage over monocultures would not be justified.

Knott and Mundt (1990) stated that mixing ability analyses, adapted from combining ability analyses used in plant breeding, were performed on yield and stripe rust (*Puccinia striiformis*) severity data for two-way mixtures among either four or five club wheat (*Triticum aesitivum*) cultivars grown in five environments. Initially, two statistics were calculated for each trait: general mixing ability (GMA), the average performance of a cultivar over all of the mixtures, and specific mixing ability (SMA), the deviation of a mixture from the estimated performance of the pair based on its average performance in mixtures. General mixing ability was further divided into two components: genotype performing ability (GPA), the innate ability of a cultivar to yield and resist disease in pure stand, and true general mixing ability (TGMA), the average ability of a cultivar to influence yield and disease when mixed with other cultivars. Significant mean squares for genotypes, GMA, SMA, and TGMA were found for all of the traits in most environments. Examination of TGMA and SMA revealed cultivars and cultivar combinations that were statistically better “mixers” than the others. Some of the significant effects were probably due to the use of cultivars that differed in height and stripe rust resistance, but for other combinations there was no apparent explanation for enhanced mixing ability.

Smithson and Lenne (1995) enumerated that remarkable parallels link the development of varietal mixtures across subsistence farming systems. Mixtures are grown and persist because they prolong harvest and income flow and provide diversity of diet. From our review of research on agronomic and disease aspects of mixtures in modern agriculture, it is also clear that improved stability and decreased disease severity are common features of mixtures relative to their components in monoculture. Such advantages are of value to both modern and subsistence agriculture. However, in the majority of cases, the yield advantage of mixtures is small. Overall, we conclude that varietal mixtures are presently a viable strategy for sustainable productivity in subsistence agriculture, have potential for improvement without sacrifice of diversity, are an important resource for future global food production and may have an expanding role in modern agriculture in situations where qualitative uniformity is not the guiding priority.

Leon and Diepenbrock (1987) found that yielding ability of intraspecific mixtures is an important issue not only for homozygous and homogeneous crops but also for heterozygous and/or heterogeneous ones. The goal of the present study was to examine the performance of mixtures and synthetics from double-low (low in erucic acid and glucosinolates) rapeseed (*Brassica napus* L.) as compared to pure stands. The material consisted of seven lines and from 1982/83 to 1984/ 85 lines, all possible biblends and syn_1's (1983/84 and 1984/85 exclusively) were grown in a completely randomized block design. An analysis of variance was conducted and general mixing effects (g.m.e.) and specific mixing effects (s.m.e.) were calculated for components of biblends. A few pure-standing lines yielded higher than some mixtures. Nevertheless, the overall mean of mixtures was not exceeded by any pure stand. For selection purposes, the higher variance of 'among lines' in comparison with 'among blends' would not result in higher yields because of the generally higher yielding ability of blends. Additionally, mixtures were marked by higher yield stability as compared to pure-standing lines. On the average of two years of testing yields of syn_1's amounted higher than yields of mixtures. Differences between 'g.m.e.' of lines were proved and moreover, the variance component of 's.m.e.' was on a lower level than that of ‘g.m.e.’ Consequently, in order to find the best mixture it seemed not necessary to analyse a complete diallel rather than to apply factorial or incomplete factorial concepts.

Patterson, et al, (1963) designed experiments to test the hypothesis that blends of 2 varieties, differing in maturity, would be less subject to lodging during storms since usually no more than 50% of the plants would be in the most susceptible stage for lodging at any given time and would receive some support from the second variety. There was also a possible advantage from blending varieties differing in height or in type of straw strength. Improvement from blends must finally be compared with the improvement possible from breeding with the available materials.

Jensen (1952) proposed that intra-varietal diversification in oats on the theoretical grounds that multiline varieties should possess broader protection against diseases and have broader adaptation than single line varieties. He suggested combining a number of lines similar in height, maturity, and appearance but differing in certain genetic factors, especially resistance to disesases. He reported combinations of six oat varieties in pairs and all together. Yields of these mixtures were generally similar but not statistically superior to the average of the varieties when grown separately.

Borlaug (1958) reported four multilineal wheat varieties in the process of development for protection against stem rust losses in Mexico. Lines within a variety differed in rust resistance but were similar agronomically.

Browning (1957) reported that yield of the blend of Glintland and Mo. 0-205 oats exceeded the mean of the 2 varieties grown in pure stands during an epidemic of race 7 of stem rust, to which Mo. 0-205 is resistant and Clintland susceptible. Less rust developed on Clintland plants in the blend than in pure stands. In one year the stiff-strawed Clintland supported the higher yielding but weak-strawed Mo. 0-205 variety.

Probst (1957) using variety blends in soybeans in the absence of diseases found that in general the blends were not superior in yield to the highest yielding variety in a blend but had a stabilizing effect on variety X year interactions. The latest maturing variety in the blend averaged 0.2 to 2.7 days earlier than the same variety in pure culture. Lodging of a blend was similar to the most lodgingsusceptible variety in the blend.

Lopez and Mundt (2000) reported that cultivar mixtures are an alternative to monoculture for crop production. Methods for predicting the performance of cultivars in mixtures would facilitate the identification of the best cultivars for mixture formation. Mean values for percent diseased leaf area (DLA) and yield under disease (YUD) of five club wheat cultivars and all possible two-way mixtures (across three Oregon locations) were used to estimate the relative contribution of each cultivar to the mixture mean (I_i) and the predicted mean of all possible mixtures (Y_m) according to the MFC method. Estimated I_i and Y_m were compared to actual mixture means. I_i allowed identification of the best cultivars for mixture formation for both DLA and YUD. Actual and predicted rank correlation coefficients for DLA and YUD of complex mixtures (more than two components) were highly significant ($P<0.01$) for the mean of the three environments (0.87 and 0.78, respectively) and for the mean of the two most relevant environments (0.83 and 0.93, respectively). Similar results were obtained when I_i and Y_m were estimated from the means of the cultivars in pure stand (instead of being estimated from the mixing ability analysis). This was due to the relatively small competitive effects (h_i) of the cultivars compared to their additive effects (v_i). Analysis was extended to data from a yield study of two-way mixtures of eight soybean cultivars, where additive and competitive effects had similar magnitude. Actual and predicted mixture means could not be compared because only two-way mixtures were included in the study. In this case, the mean yield of the cultivars in pure stand was not a good predictor of the performance of cultivars in mixtures. Ra 604, the third highest yielding cultivar, had a positive additive effect (v_i=53.8 kg/ha), but a highly negative competitive effect (h_i=−49.7 kg/ha) that resulted in a negative contribution (I_i) to yield when mixed with the other soybean cultivars. Additive (v_i) and competitive effects (h_i) must be considered to obtain superior mixtures, and the advantage of I_i is that it takes into account both effects ($I_i = \frac{1}{2}v_i + (k - 1/k)h_i$) , *k* is the number of cultivars). The MFC method may be a useful tool to select desirable cultivars to obtain complex mixtures.

Finckh et al. (1999) studied the effects of frequency and density of susceptible plants on barley powdery mildew epidemics were studied in a combined set of addition and replacement series of field trials. In the addition series, plant densities in purestands of three cultivars, Rambo, Rodos and Grosso (susceptible, moderately resistant and immune, respectively) were varied six-fold. In the replacement series, the three possible two-way mixtures were analysed at different frequencies but at a density corresponding to the maximum pure stand density. Disease and yield were assessed on a per-plant basis. In the pure stands, tillering reduced the range of densities from six-fold to between three- and four-fold, while in the mixtures, frequencies changed only slightly over time, indicating that competitive interactions among the cultivars were roughly equal. Yield per plant decreased logarithmically with increasing density as expected. However, yield per seed head was not correlated with the final number of heads per plot, indicating low competition among heads even at the highest density. Disease in susceptible pure stands increased strongly with decreasing density in 1994 and to a lesser degree in 1995. These differences could have been caused by differences in plant nutritional status and consequent epidemiological effects. Disease reduction on the susceptible cultivars in mixtures varied between 33% and 71% among years. Dependingon the length and strength of the epidemic, the effects of host density and frequency on disease severity varied substantially among years.

Newton et al. (1998)$_a$ stated that a range of winter barley cultivars was grown either as pure stands or as components of mixtures, in a trial in 1995-96. For malting quality characters, mean values of mixtures did not differ from mean values of the appropriate monocultures except for decreases in homogeneity, as determined by a fluorescence test of cell wall modification. When disease pressure was modified by fungicide, hot water extract was not significantly altered, although this may have been due to the restriction of malting to grain retained by a 2.5 mm sieve. One mixture, comprised of three related winter malting cultivars, gave higher hot water extracts than its components, as pure stands, with no adverse effects on homogeneity. This was not simply attributable to lower grain nitrogen content.

Newton et al. (1998)$_b$ conducted an experiment to determine the effects of a resistance elicitor and cultivar mixtures on genetic complexity and diversity in against to powdery mildew populations. Isolations were made from a range of spring barley monocultures and mixtures in a field trial, and characterized for virulence and RAPD profile. In a second trial, isolates were taken from a single mixture from untreated and resistance elicitor-treated areas and from the components of the mixture in monoculture. The mildew population was not only highly heterogeneous for virulence characteristics, but also proved heterogeneous within pathotypes for molecular markers, indicating the major impact of sexual recombination on population structure and the lack of clonal dominance. Various diversity measurements were compared and the value of dissimilarity measurement for revealing genetic distance within a population was highlighted. There was a trend towards increasing complexity as the season progressed, but there was no consistent relationship between cultivar or mixture, disease control treatment, fertilizer treatment, replicate or position in trial, and pathogen genotype. Whilst the resistance elicitor did reduce mildew by 78% in the first trial, and there was no interaction with fertilizer level in its expression, control was substantially less in the second trial. There were no differences between mildew isolates from elicitor and control treatments. It was felt that more effective and consistent resistance elicitors need to be developed before it can be stated that they are unlikely to be eroded by selecting resistant or adapted mildew genotypes.

Walsh and Noonan (1998) carried out two field trials at Lyons Research farm in 1995. Three advanced generation lines and three equiproportional binary mixtures derived from them were grown under two nitrogen fertilization regimes in each trial One trial was treated with fungicide and the other was untreated. The primary objective of this study was to assess any agronomic or quality benefits arising from the use of spring wheat variety mixtures under Irish conditions. Even though disease pressure was light, mixtures were superior to components (in monoculture) in terms of powdery mildew (*Erysiphe graminis*) restriction Disease restriction in mixtures did not lead to detectable yield benefits. There was no evidence of yield benefits or yield penalties attributable to mixtures and neither nitrogen or fungicide regime had a discernible effect on the performance of mixtures relative to their components. This study also revealed that there were no apparent benefits from the use of mixtures in terms of improved milling or baking quality. Overall, the results indicate that, under the conditions of this trial the use of mixtures did whatever any beneficial or adverse effect. It is arguable that if disease pressure had been greater, or if conditions in general had been marginal, benefits of blending might have been more obvious.

Ninkovic et al. (2003) conducted experiment of four barley varieties with no significant difference in aphid acceptance were sown in pure stands and in pair wise combinations with varieties side by side in separate rows. Settling tests were done in situ in the field plots with apterae of *Rhopalosiphum padi* (L.) (Homoptera: Aphididae) and showed that aphid acceptance was changed in some combinations of cultivars. In a laboratory test, in which plants of one cultivar were exposed to air from the other cultivars, aphid acceptance was significantly reduced in three of the four cultivars when treated with air from certain other cultivars. Two of these three cultivars showed the same reduction under field conditions. This supports the hypothesis that plant/plant communication may release responses in neighboring plants that change aphid host plant acceptance. The results also show that this mechanism is not restricted to optimal growing conditions in the laboratory, although it may be modified under field conditions depending on plant genotype.

Yadav and Yadav, (2000) studied dryland sustainable agriculture in the arid zone of India depends upon the choice of suitable cultivars for pure and mixed crop stands. Field experiments were conducted for two years to examine the response of two contrasting cultivars each of pearl millet (*Pennisetum glaucum*) and clusterbean (*Cyamopsis tetragonoloba*) in pure stands and in mixed pearl millet-clusterbean stands. The differential response of cultivars of both crops to pure and mixed stands resulted in a significant genotype x cropping system interaction. Reduction in seed yield of both clusterbean cultivars was greater in mixed stands with tall and long duration pearl millet MH 179 than with medium statured and early maturing HHB 67. The degree of reduction was greater in Naveen, the branched clusterbean cultivar, than in RGC 197, the single stemmed cultivar. Mixing of pearl millet HHB 67 with medium duration clusterbean cultivar Naveen produced maximum pearl millet equivalent total yield. Higher land equivalent ratios (LERs) were also observed when clusterbean cultivars were mixed with early maturing and short statured pearl millet HHB 67.

Eva (2006) reported while it is known that mixtures of cultivars generally stabilise crop yields and reduce losses caused by diseases, their influence on weeds has not yet been thoroughly investigated. Competitive effects against weeds are dependent on specific plant characteristics, which can vary between cultivars. The aim of this study was to investigate whether mixtures of barley cultivars with different characteristics could suppress weeds better than barley grown in pure stands, and whether the weed suppressive effect differed between the mixtures.

A greenhouse trial was performed with three two-rowed spring barley (*Hordeum vulgare* L. spp. vulgare) cultivars grown in pure stands, all possible two-cultivar mixtures and the three-cultivar mixture. The barley cultivars Hydrogen, Henni and Troon were chosen because they differ in the three characteristics allelopathic activity, root length development and shoot length in the first growth stages. Turnip rape (*Brassica rapa* cv. Agat) and perennial ryegrass (*Lolium perenne* cv. Helmer) were chosen as model weed flora.

The results indicate that cultivar mixtures can improve the competitive ability of barley, reducing biomass production by weeds and diminishing barley biomass losses. Contrasting allelopathic activity and shoot development characteristics in the mixture increased the competitive effect. The weed suppressive effect differed between mixtures and was lowest in the mixture with differing root development but low shoot development and high allelopathic activity. Mixtures did not express the sum of characteristics of each individual barley cultivar. In fact, on some occasions the mixture that showed the best competitive ability did not contain the cultivar that demonstrated the best competitive ability when grown in pure stand. The mixtures that included cv. Hydrogen, which has high allelopathic activity, improved the competitive response in terms of barley biomass.

Mixture design is needed to get cultivar mixtures that can control weeds. More research is needed on this aspect to devise a formula that allows us to design correct mixtures, and therefore to use cultivar mixing as a method for controlling weeds.

Wheat cultivars and cultivar mixtures were grown and studied Mundt (2002) in commercial fields naturally infested with *Cephalosporium gramanium*. Thirteen treatments, including nine cultivars and four two-way cultivar mixtures, were replicated four times in 3×30 m plots in each of six experiments (two locations×three winter wheat seasons). Cephalosporium stripe was quantified by estimating the percentage of prematurely ripening heads (whiteheads) in each plot. There was little variation in percentage of whiteheads among club wheat entries, which were less susceptible than the common soft white winter wheats. Common wheat entries varied from highly susceptible to moderately resistant. One cultivar mixture significantly ($P<0.01$) increased the percentage of whiteheads as compared to the mean of its component cultivars grown in pure stand in four of the six experiments; mixtures never significantly decreased the percentage of whiteheads. All four cultivar mixtures significantly reduced lodging in the one experiment where there was sufficient eyespot (caused by *Pseudocercosporella herpotrichoides*) to cause lodging. Averaged over the six experiments, the four cultivar mixtures yielded 7.5, 6.9, 3.4, and −1.7% more than the means of their component cultivars grown in pure stand; the highest yielding club wheat and the highest yielding common wheat treatment were both cultivar mixtures. Cultivars varied in parameters of yield stability, with no obvious difference between susceptible and resistant cultivars. Cultivar mixtures demonstrated greater yield stability than did the individual cultivars.

Manthey and Fehrmann (1993) studied cultivar mixtures in wheat decreased disease development and gave higher yields than pure stands in field trials over two seasons. Spring wheat usually gave higher yield responses than winter wheat. Delays in disease development were clearly observed for powdery mildew (*Erysiphe graminis*) and leaf rust (*Puccinia recondita*). A tendency towards delayed development was observed for stripe rust (*Puccinia striiformis*). For assessment of non-specialized pathogens (*Fusarium* spp., *Septoria nodorum*), numbers of conidia on leaves were counted and found to be reduced on leaves of cultivar mixtures. Yield increase in the best winter wheat mixture was on average 5.1 % and in the best spring wheat mixture 5.7% (without fungicide treatment). Cultivar mixtures gave a higher profit than the respective pure stands. F_1 and F_2 hybrids were compared with the corresponding two-cultivar mixtures, but did not show promise with regard to profitability.

Sammons and Baenziger (1985) conducted a field experiment for 4 years at two locations in Maryland to evaluate the performance of 11 blended populations of winter wheat (*Triticum aestivum* L.) relative to their four component cultivars (‘Blueboy’, ‘Centurk’, ‘Holley’, ‘Potomac’) in pure stands. All possible equal proportional 2-, 3-, and 4-way mechanical blends were prepared for evaluation.

Blends and component cultivars were grown in replicated small plots (1.22 m × 3.05 m) under conventional management for wheat in Maryland. Plots were scored for lodging, winter survival, and incidence of powdery mildew (*Erysiphe graminis* f. sp. *tritici*). At maturity, a yield estimate was obtained, and grain samples were analyzed for milling and baking quality. Advantages for several blend populations relative to some of the component lines in pure stand were observed for yield, standability, and winter survival. Data for mildew incidence in the blends was inconclusive, and no advantages were observed for milling and baking quality relative to the component lines. It was concluded that (1) it should be possible to construct agronomically suitable blends; (2) their relative performance can be predicted based on the known performance of component cultivars grown in pure stands; and (3) that their use in world agriculture can make an important contribution towards a reduction in the risks inherent in genetic uniformity.

Field experiments conducted by Brophy and Mundt (1991) at two sites across two winter wheat (*Triticum aestivum* L.) seasons tested the effects of cultivar mixtures and spatial planting patterns on foliar disease development and wheat yield. Two or three wheat cultivars were planted in pure stands, random mixtures, alternating rows, and alternating four-row swaths. Plots were inoculated with leaf rust (induced by *Puccinia recondita* Rob. ex Desm.) or stripe rust (induced by Puccinia striiformis West.). Fungicide-treated control plots consisted of a random mixture pattern (first season) or all patterns used in inoculated plots (second season).

Random mixtures and alternating rows of cultivars reduced rust severity 15–82% compared with the mean severity in pure stands. Alternating swaths plots showed higher disease than the random mixture, but also yielded as high or higher than the random mixture. Disease control results are explained by the size of the contiguous are occupied by a given cultivar, which is small for a random mixture, larger for alternating rows, and largest for alternating swaths. Mixtures reduced disease more effectively when this contiguous area was small than when it was large. In the absence of disease, the random mixture yielded similarly to or higher than alternating swaths.

During the second season, yield in mixtures was dominated by one cultivar under conditions of disease pressure or close proximity (the random mixture), but yield was more evenly divided between the two cultivars in disease-free plots or in alternating swaths. Thus, planting pattern and disease interacted to influence yield by changing the competitive interactions among cultivars in the mixtures. The planting pattern used in cultivar mixtures may be important in determining disease control and yield results.

Eagles (1982) reported Swards were developed from plants of contrasting populations of *Dactylis glomerata* L. selected for high and low dry-matter (DM) production in monocultures and mixed cultures grown during 1970 and 1971. DM production of these mono-genotype swards was assessed during 1974. Those swards developed from the divergent selections from monocultures maintained a significant difference between the high and low selections, whereas those developed from selections out of mixed cultures showed no significant difference in yield. These results are consistent with earlier reports that there is no positive relationship between competitive ability in mixed cultures and vigor in pure stands. The implications of the physiological basis of these responses in terms of grass breeding are discussed.

2.2. Intergenotypic Competition

Soybean (*Glycine max* L.) cultivars KS 8 and TNG 15, different in colors of flowers and young stem as genotypic markers were grown both in monoculture and mixture under various spacing. They were arranged in a way so that the effects of 1- and 2-plant per hole and hole distance on the selection effectiveness and early or latter segregating generation populations can be determined Lin et al, (1991) indicated that there were significant difference between the plants of monoculture and mixture on the total dry weight and seed number. Whereas, seed yields and other characteristics, such as plant height, node and branch numbers, days to maturity, 100-seed weight, and harvest index, were found no significant differences. Plants grown 2-plant per hole had higher plant height, total dry weight, and harvest index with fewer branches and seed numbers than those grown in 1-plant per hole. Similar effects occurred with different hole distances.Furthermore, it was shown that selection for soybean yield was not affected by plant numbers per hole and hole distances if the same population size per unit ground area was used.

Chowdhry *et al.* (1998) compared the performance of ten biblends, each grown in a 1:1 genotypic ratio, with the performance of the involved five bread wheat genotypes grown in pure stands. Land Equivalent Ratio (LER) was calculated by using the concept of de Wit and van den Berg (1965). Most of the biblends exhibited reduction in biomass and grain yield per plant than their respective mid component of pure stand. However, two biblends, Rohtas 90-Chakwal 86 and 6500-Chakwal 86 showed significant increase of 9.40 and 16.36 percent for biomass yield (LER values of 1.10 and 1.16) and 14.26 and 18.73 percent for grain yield per plant (LER values of 1.15 and 1.19), respectively. It was concludes that varietal mixtures do have potential as a means of increasing crop yield but identification of correct genotypic combination is essential.

Helland and Holland (2003) found genetically diverse plant populations may be better able to exploit ecological resources and reduce interplant competition than genetically homogeneous populations. Cultivar blends can have greater productivity and yield stability than pure lines; however blend effects are not consistent. The varying levels of genetic diversity represented in blends may confound the interpretations and comparisons of the results of different blend studies. We tested the hypothesis that genetic diversity of blend components is related to blend performance by evaluating blends of a set of five early-maturing and a set of 10 midseason-maturing oat (*Avena sativa* L.) cultivars in two separate experiments at eight Iowa environments. Within each experiment, pure lines and all possible two-way blends were evaluated for grain yield and test weight means and stability and adaptability parameters. The genetic diversity of each blend was estimated by pedigree diversity [1 - coefficient of parentage (COP)], amplified fragment length polymorphism (AFLP)-derived genetic distances (1 - Dice coefficient), and phenotypic diversity (based on height and heading date differences). Blend response was limited in these experiments and was not correlated with any diversity measure, and blend stability parameters were not consistently related to diversity measures across experiments. We also investigated the relationship between pedigree diversity and blend performance in other crops by computing the coefficients of parentage of cultivar pairs used in previous blend studies in maize, soybean, and wheat. Pedigree diversity was correlated with higher blend response only in two of 10 experiment-environment combinations tested. Genome-wide genetic diversity alone does not cause positive crop blend responses.

The competitive ability (defined as root yield in mixture/root yield in monoculture) of Cassava (*Manihot esculenta* Crantz) genotypes in monoculture, mixed populations and in multiple cropping systems was studied by Kawano and Thung (1992) in the field. Strong competitors produced more roots and stems in genotypic mixtures than in monoculture and did so at the expense of weak competitors. Competitive ability was positively correlated with spacing response and stem and leaf-weight at harvest, but negatively correlated with harvest index (proportion of root weight to total plant weight) and root yield in monoculture. Because of the negative correlation of competitive ability with root yield in monoculture, improvement in the productivity of cassava cultivars will likely occur through improvements in plant efficiency and at the expense of competitive ability. It is therefore recommended that in selecting high yielding genotypes potentially adapted to productive environments, strong competitors should be eliminated from segregating populations. Modest yield reductions (9 to 13%) occured when cassava was planted in association with beans (*Phaseolus vulgaris* L.) or soybeans [*Glycine max* (L.) Merrill]. Beans, planted in association with cassava, had non-significant reductions in yields whereas yields of soybeans were severely reduced. Yields of beans and soybeans were negatively correlated with vegetative vigor of the associated cassava genotype, but were not correlated with yield or intergenotypic competitive ability of the cassava genotype. Cassava can be planted in association with short-duration crops without sacrificing much in the yields of either crop. High-yielding cassava genotypes with low vegetative vigor would bring about high combined yields of cassava and the associated crop.

Intergenotypic competition among soybean (*Glycine max* (L.) Merrill) cultivars were evaluated by Gedge et al, (1977) in competing row plots and in two-component blends. The objectives were to determine the importance of intergenotypic competition on soybean performance in unbordered plots and to evaluate the use of estimates of interplot competition for predicting intergenotypic competition in blends. Five soybean cultivars, ‘Chippewa 64’, ‘Hark’, ‘Corsoy’, ‘Provar’, and ‘Amsoy’, were grown in three-row plots with 25, 50, 75, and 100 cm between rows. The center row was the test cultivar, and the border rows were either the cultivar itself (pure stand) or one of the four other cultivars. All possible pairs of the five cultivars were tested in a northern and a central Iowa location for 2 years. The average change in yield caused by intergenotypic competition increased from 2.6% in 100-cm rows to 17.6% in 25-cm rows. Significant yield changes occurred at all row spacings, particularly when Amsoy was either the test cultivar or the competing cultivar. Maturity, height, and lodging were not significantly affected by competition at any row spacing. Soybean yield tests with cultivars and growing conditions similar to Iowa should use bordered plots if no bias from intergenotypic competition can be tolerated. The soybean cultivars were grown in two-component blends at the ratios 3:1, 1:1, and 1:3. The blends contained cultivars with different pubescence color so they could be harvested separately. The blends and pure stands of each cultivar were grown in bordered plots spaced 68 cm apart. The blend test was grown adjacent to the interplot competition test in all environments. Intergenotypic competition in blends was most closely predicted by competition between 25-cm rows, but the relative competitive ability of cultivars in blends was not always the same as their relative competitive ability in adjacent rows.

The effect of inter-genotypic competition on yield and other attributes was evaluated Schutz and Brim (1967) in both hill and row plots utilizing four diverse adapted varieties. The experimental design permitted the measurement of competition dosage effects as well as compensatory effects on adjoining genotypes. There was a drastic effect of competition in hills and rows on seed yield, seed number, and efficiency (expressed as a ratio of seed yield to straw yield). Certain genotypic combinations exhibited overcompensatory effects, a result which suggests that genotypic behavior in a competitive situation may be a reliable criterion for predictlng superior varietal blends. The data further suggest a nine-hill field plot which should be effective in evaluating large populations for superior yield genotypes. The nine hill plot removes about 70% of the competition bias exhibited by an unbordered hill and would require much less land area and seed for testing than standard row plots.

Yield data from four soybean [*Glycine max* (L.) Merrill] varieties, six two-component mixtures, and four three-component mixtures were used by Schutz and Brim (1971) to study the effect of intergenotypic competition on population stability. Yield tests were conducted in three-row plots at four locations in each of four years. Stability was measured by estimating the relative contributions of pure lines and mixtures to the first and second order interactions of entries, locations, and years; by constructing frequency distributions of rank order; and by regression and deviations from regression of population performance on environmental productivity. Three of the six two-component mixtures exceeded their component means by a significant amount and were arbitrarily classified as overcompensatory. Two-component mixtures with yields similar to their component means were classified as complementary. Mixtures were generally more stable than the pure lines, with the degree of stability apparently dependent upon the type of competitive interaction involved. Variance component analysis indicated that overcompensatory mixtures made a very small contribution to the entry x location component of variance while complementary mixtures contributed heavily to σ^2_{EL}. However, overcompensatory mixtures produced a large entry x location x year interaction component in contrast to the small value obtained for the complementary group. The results suggest that overcompensatory competition effects are influenced by random environmental factors but that complementary effects are associated with environmental factors indigenous to a test location. Thus, both overcompensatory and complementary competition effects appear to be essential to obtain a high degree of stability in a heterogeneous population. Although complementary effects do not enhance reproductive output to any significant extent, their stabilizing influence may be an important factor in evolutionary population dynamics.

Experimental designs and various analytical approaches can now be used by Castilla et al, (2003) to evaluate disease epidemics and interactions of cultivars in mixtures and, consequently, allow for a more efficient identification of a system that suppresses diseases and maximizes positive interactions among cultivars. Moreover, various farmer participatory methods can be applied to ensure that a given system suits the social, cultural, and economic needs of farmers. Using a combination of these approaches, on-farm experiments are under way in China, the Philippines, and Indonesia to explore the use of rice cultivar mixtures.

The effects of cultivar mixtures and two irrigation frequency treatments were evaluated by Rush and Harveson (2002) over two seasons for their impact on a complex of sugar beet root diseases in three fields infested with the fungal pathogens *Aphanomyces cochliodes*, *Fusarium oxysporum* f. sp. *radicis-betae*, *Rhizoctonia solani*, and the viral pathogen *Beet necrotic yellow vein virus* (BNYVV). Irrigations after emergence consisted of two or five (two 1994 studies) and three or six (1995 study) applications of water for dry and wet treatments, respectively. Cultivar treatments included MH9155, HH67, Ranger, Rhizosen, and four combinations of these same cultivars. Disease progress was monitored through destructive sampling of plants exhibiting foliar symptoms typical of root disease during the season. At harvest, data on root and sucrose yields, sucrose percentage, and a root disease index were collected. No significant irrigation × cultivar treatment interactions were observed. Few significant differences were observed between irrigation treatments involving measured yield components. Reduced irrigations however, resulted in significantly lower disease incidence in all three repeated experiments when cultivar treatments were combined. No added benefits were observed for increasing yield or decreasing root disease by planting mixed cultivars, compared to the same cultivars planted individually. Several regionally adapted cultivars performed as well or better than mixtures under the unusually high levels of disease pressure in test fields. When few alternative options are available, sugar beet growers may still benefit from reducing irrigations, and growing locally adapted cultivars in soils severely infested with root pathogens.

Four winter wheat (*Triticum aestivum*) cultivars and three two-component cultivar mixtures were planted by Akanda and Mundt (1997) in a replacement series both inoculated with or protected from yellow rust (*Puccinia striiformis*) in three environments. Each cultivar was susceptible to one or two of the rust races used. Mixtures yielded, on average, 7 and 4% more than their component pure stand means under inoculated and rust-free conditions, respectively. Though all yield components were affected by yellow rust, seed weight was the component that was most consistently influenced. The component genotypes within mixtures varied considerably with respect to yield, and the yield of the same component cultivar included in different mixtures sometimes differed significantly. The correlation between yellow rust severity/tiller and grain yield/tiller in mixture differed among cultivars and depended on their companion cultivar. Variance component analysis indicated that yellow rust was the most important experimental variable influencing grain yield. There was no relationship between yield of the cultivars in pure stands and their yields or competitive abilities in mixture. Disease did not change the competitive ranking of cultivars in mixture. Mixtures with complementary, negative, and overcompensatory interactions were identified. On average, mixtures showed no greater yield stability than did pure stands. The effects of competition may disguise the true value of progenies in practical maize breeding nurseries, where large numbers of progenies are evaluated in small plots. These effects may be exacerbated where growth factors limit performance. Intergenotypic competition among 72 randomly selected maize (*Zea mays* L.) S_1 progenies was examined when grown in non-bordered 1- and 2-row plots and in self-bordered 4-row plots, each at limited N (0 kg ha^{-1} applied) and adequate N (200 kg ha^{-1} applied). The same randomization plan was used for each comparison. Traits examined were anthesis date, plant height, ear-leaf chlorophyll concentration, number of green leaves below the ear at two dates during grain filling, leaf disease (*Exserohilum turcicum*) score, and grain yield. Significant correlations between the difference of progeny performance in non- versus self-bordered plots and mean performance of adjacent plots were detected, indicating the presence of intergenotypic competition under both N levels. Changes in rank that occurred between progenies grown in non- versus self-bordered plots did not, however, lead to statistically significant progeny × plot-size interactions. With limited N supply, the residual variance of progenies when grown in the smaller non-bordered plots was usually less than when grown in the larger, self-bordered plots, indicating that soil heterogeneity was probably the main source of residual variance in that trial. Generally, intergenotypic competition explained less than 10% of the difference in performance of progenies in non- versus self-bordered plots. It is concluded that statistical procedures and additional bordering, which would reduce the effects of intergenotypic competition, would only marginally improve selection efficiency in progeny trials, and that under most conditions the extra expenditure on seed and land that these entail would not be justified.

Rao and Prasad (1984) studied the grain yield and yield components in the three spring wheat genotypes HD 2160 (dwarf), Kalyansona (semi-dwarf) and C 306 (tall) in pure stands as well as in their binary mixed stands during two years. The grain yields of the three genotypes in pure stands ranked as follows: HD 2160 > Kalyansona > C 306. Four mixed stands, 3:1 HD: K, 1:1 HD: C in the first year and 1:1 K: C, 1:3 K: C in the second year out-yielded the pure stand of the better component genotype by 4.4, 2.7, 3.3 and 0.8 percent, respectively. Out of the nine mixed stands four in the first year and seven in the second year out-yielded the midmonoculture yields and the increases ranged from 1 to 7.6 percent. Mixed stands were more stable than pure stands. The yield and yield components of the dwarf genotype HD 2160 scored less and those of the taller genotype C 306 scored higher in mixed stands. The semi-dwarf genotype Kalyansona yielded more with HD 2160 and less with C 306. Plant height but not high yielding ability conferred high competitive ability. With respect to competitive ability the three genotypes ranked as follows: C 306 > Kalyansona > HD 2160.The results illustrate the importance of intergenotypic competition in increasing crop production and reducing genotype-environment interactions. Such studies are important to agronomists as genotypes with high competitive ability can be useful to combat the weed problem. They are also important to plant breeders for predicting the fate of genotypes with low competitive ability in heterogeneous populations.

In field experiments, the competition among plants of two distinct wheat genotypes in binary mixtures, and among three genotypes being grown in adjacent rows was investigated by Smocek (1974). The competition greatly affected the over-ground dry weight, weight of stem and grain per plant. This effect was undercompensatory; the depression in poor competitor was higher than the enhancement of strong competitor for all these characteristics. From final components of grain yield per plant, the number of fertile stems and number of grains per ear were more affected than weight per grain. More expressively than weight of grain on the main-stem ear, the weight of grain per average secondary ear-bearing stem was affected by competition in binary mixture. The enhancement in standard height—a strongly competitive genotype— reached in binary mixture about 10% for this last characteristic in comparison with the value from the pure stand. Some morphological characteristics of plants being in relation with competition for grain yield per plant are discussed in these experiments.

Adams et al (1973) investigated the effects of competition on the growth of families of loblolly pine (*Pinus taeda*, L.) seedlings. The experimental design made it possible to evaluate the effects of crowding on growth and to determine the types and magnitudes of intergenotypic interactions among pairs of families. The results showed that intergenotypic interactions were both highly variable and pronounced in their effect on early growth. Evidence was also found for precompetition cooperating interactions occurring among seedlings surrounded by neighbors of the same family.

Four experimental single-cross hybrids were evaluated by Tovar and Compton (1974) for intergenotypic competition in a split-plot design with 7 replicates and a stand density of 51,700 plants/hectar in 1970, 1971 and 1972 at Lincoln, Nebraska. The arrangement of rows used in this study allowed the measurement of effects of different levels of competition on the traits grain yield, plant height and a selection index. There were some definite inter-genotypic competitive effects for all three traits among the pairs of hybrids studied. Variation in types of intergenotypic interaction was found. A two-step process was suggested to take advantage of favorable competitive interactions for increasing grain yield. Failure of mixtures in corn to take advantage of favorable competitive situations was discussed.

Carter et al, (1989) reported that the divergent maturity of blend components is a major factor leading to the positive blend responses sometimes noted in soybean [*Glycine max* (L.) Men.]. The objective of this study was to examine the association between cultivar maturity and blend performance in determinate soybean. Eight purelines (four from maturity group [MG] V and VII), and the 28 two-way blend combinations of these purelines were evaluated for seed yield in eight North Carolina environments. Blend responses (expressed as a deviation of the blend yield from pure-stand component average) were 0.1, 1.9, and 3.3% for MG V, intermaturity (MG V/ MG VII), and MG VII blends, respectively. The intermediate average response of the intermaturity (MG V/MG VII) blends is an indication that divergent maturity of the blend components has little effect on blend performance. This notion is further substantiated in that individual positive blend responses occurred more frequently in the MG VII blends than in the MG V/MG VII blends. Only the MG VII blend group showed a significant overall blend response (84 kg ha^{-1}). The highest yielding MG V/MG VII blend, that of 'Coker 237' (MG VII) with 'N77-114' (MG V), was composed of component cultivars that blended well even when no maturity factors were evident. We conclude that maturity differences may be incidental to better blend performance in determinate soybean. The range of individual blend responses was –9.7 to 9.1%, expressed as deviations from pureline component averages.

Prakish et al, (2006) found that differences between the isolines in a multiline may result in differences in competitive ability and lead to changes in the frequency of the components after a few cycles of multiplication. Alternative-row design of Hanson et al. (1961) was used to detect and characterize the presence of intergenotypic interactions among eight isolines of a multiline of bread-wheat 'Kalyansona'. The material was grown in 1.5 meter row plots using a unique sequence of arrangement. The observations were recorded with respect to plant height and grain yield per plant. The results of the analysis showed the components of variance for average competitive ability and specific combination to be highly significant, indicating the existence of intergenotypic interactions. Significant genotypic differences between isolines revealed that the genotype of the recurrent parent had not been fully reconstituted. On the basis of the effect of the border genotype averaged over all the genotypes (Ck.), the genotypes were classified into four groups, viz. a) highly depressive, b) mildly depressive, c) mildly cooperative and d) highly cooperative. Categories c and d were indicated as useful for the synthesis of multilines.

Annicchiarico and Piano (1997) noted that six white clover genotypes that were easily distinguishable from each other on the basis of leaf lamina marks and morphology were grown at Lodi, Italy, during 1990 and 1991 in dense swards, under field conditions and a mowing regime, as (i) pure stands, (ii) a complex mixture of all genotypes, (iii) binary mixtures of each genotype with each of two ryegrass varieties, and (iv) complex mixtures of all clover genotypes in binary association with each grass variety. The grass components were of known, different vigor. The study assessed both intergenotypic and interspecific interference and related dry matter yield responses to morpho-physiological traits of the clovers, and also determined whether a high level of morpho-physiological heterogeneity conferred a yield advantage on clover populations. Greater heterogeneity (i.e. a complex mixture of clover genotypes) did not produce higher clover yields either in the presence or absence of interspecific interference from grass; thus, the use of blends of varieties or the development of varieties with a fairly high degree of heterogeneity was not recommended for short-term meadows in environments with relatively low spatial and temporal variability. Interactions for yield occurred between clover genotypes and the presence or absence of intergenotypic interference ($P<0{\cdot}001$), and between clover genotypes and the presence or absence of interspecific interference from the grass variety characterized by greater vigour and aggressiveness ($P<0{\cdot}01$). The variance of the former interaction tended to be consistently larger than that of the latter interaction, indicating that competitive effects were greater between clovers than between the clover and grass components. A lower Spring [ratio] Summer yield ratio and taller canopy tended to confer a competitive advantage under intergenotypic interference. Relatively better performance under interspecific interference was related to higher stolon density, suggesting that selection for this trait may increase the general ecological compatibility of large-leaved white clover types grown with vigorous grass companions.

Five wheat varieties/lines were sown by Akram (2002) in a diallel fashion. There were ten mixtures and five pure stands. The genotypes manifested a differential behaviour for all the morphological characters i.e., plant height, number of tillers, spike length, number of spikelets per spike, number of grains per spike, 1000-grain weight and also the economic yield. The LER values were 1.15, 1.18, 1.01, 1.15 and 1.09 for the five combinations MH- 97 + Pb.96, MH-97 + Inqilab 91, MH-97 + LU26S, Pb.96 + LU26S and Inqilab 91 + Uqab 2000 indicating 15.26, 18.10, 1.56, 15.26 and 7.75 % increase in grain yield over their mid parents, respectively. However, the remaining mixtures reduced in grain yield. It was also observed that the differences between components may produce differences in their competitive ability, but the competitive and yielding ability of genotypes are not always synonymous. It is evident from this experiment that genotype mixtures can utilize environmental resources more efficiently than their pure stands. The varietal mixtures do have potential as a means of increasing crop yields, but identification of correct genotype combination is very essential.

The consequences of elevated CO_2 on plant growth have been well studied by Christophe et al, (2001) on individual plants. The response of a more complex system with several plants interacting is less understood—a situation that limits our capacity to predict the response of natural plant communities. In this study we analyzed the effect of CO_2 enrichment on intergenotypic competition in *Arabidopsis thaliana*. Seeds of five genotypes collected from different natural populations were used. Each genotype was cultivated in a pure stand and in a mixture with each of the other four genotypes in two CO_2 conditions (ambient and elevated). At harvest time, genotype fitness was estimated by the number of fruits and seeds produced per plant. At current levels of CO_2, genotypes performed better in a pure stand than in a mixture. Kin selection, associated with the low seed dispersal and autogamous reproductive regime of *A. thaliana,* is invoked to explain these positive responses among plants of similar genotype. Surprisingly, in a high-CO_2 atmosphere (700 μL/L) the reverse situation was observed: plants performed better in mixtures than in pure stands. Positive frequency-dependent selection under ambient CO_2 concentration became negative under elevated CO_2, which could lead more easily to the maintenance of genetic variation. This hypothesis was tested with a simple model of competition. At equilibrium, the simulation did not show coexistence among more genotypes under elevated CO_2 than under ambient CO_2 concentration. However, this study allows predictions about evolutionary trajectories under high-CO_2 conditions. In *A. thaliana*, genotypes that will maintain the most their ability to grow well in pure stand should be selected under increasing CO_2.

The effects of inter-genotypic competition were studied by Roy (1976) in wheat under conditions of single seed descent in the glasshouse. Four genotypes were grown mixed in diallelic combinations of two, making six mixtures and four component (pure) stands. It was found that genotypic differences in most cases over-rode initial effects of phenotypic differences in seed size, and played a dominant role in determining what plants, if any, were eliminated from the mixtures. Low genotypic competitive ability accounted for 8 to 14% losses, in a single generation, in representation in the population through failure to produce at least one fertile tiller. Howerver, under single seed descent where artificial selection assures retention if even only one seed is produced, the loss of weak competitors was slower than it might have been under natural selection in the field.

The consequences of elevated CO_2 on plant growth have been well studied by Andalo et al (2001) on individual plants. The response of a more complex system with several plants interacting is less understood—a situation that limits our capacity to predict the response of natural plant communities. In this study we analyzed the effect of CO_2 enrichment on intergenotypic competition in *Arabidopsis thaliana.* Seeds of five genotypes collected from different natural populations were used. Each genotype was cultivated in a pure stand and in a mixture with each of the other four genotypes in two CO_2 conditions (ambient and elevated). At current levels of CO_2, genotypes performed better in a pure stand than in a mixture. Kin selection, associated with the low seed dispersal and autogamous reproductive regime of *A. thaliana,* is invoked to explain these positive responses among plants of similar genotype. Surprisingly, in a high-CO_2 atmosphere (700 µL/L) the reverse situation was observed: plants performed better in mixtures than in pure stands. Positive frequency-dependent selection under ambient CO_2 concentration became negative under elevated CO_2, which could lead more easily to the maintenance of genetic variation. This hypothesis was tested with a simple model of competition. At equilibrium, the simulation did not show coexistence among more genotypes under elevated CO_2 than under ambient CO_2 concentration. However, this study allows predictions about evolutionary trajectories under high-CO_2 conditions. In *A. thaliana,* genotypes that will maintain the most their ability to grow well in pure stand should be selected under increasing CO_2.

Grain yield and yield components were studied by Rao and Prasad (1984) in the three spring wheat genotypes HD 2160 (dwarf), Kalyansona (semi-dwarf) and C 306 (tall) in pure stands as well as in their binary mixed stands during two years. The grain yields of the three genotypes in pure stands ranked as follows: HD 2160 > Kalyansona > C 306. Four mixed stands, 3:1 HD:K, 1:1 HD:C in the first year and 1:1 K:C, 1:3 K:C in the second year out-yielded the pure stand of the better component genotype by 4.4, 2.7, 3.3 and 0.8 percent, respectively. Out of the nine mixed stands four in the first year and seven in the second year out-yielded the midmonoculture yields and the increases ranged from 1 to 7.6 percent. Mixed stands were more stable than pure stands.

The results illustrate the importance of intergenotypic competition in increasing crop production and reducing genotype-environment interactions. Such studies are important to agronomists as genotypes with high competitive ability can be useful to combat the weed problem. They are also important to plant breeders for predicting the fate of genotypes with low competitive ability in heterogeneous populations.

MATERIALS AND METHODS

CHAPTER III

MATERIALS AND METHODS

The experiment was conducted at the Research farm of Sher-e-Bangla Agricultural University, Dhaka-1207 during the period from late March to mid June, 2007. Detailed of the experimental materials and methods followed in the study are presented in this chapter. The experiment was conducted to study the mixing ability and inter-genotypic competition from 7x7 uni-blends and bi-blends of mungbean (*vigna radiata* (l.) Wilczek) genotype.

3.1 Site description

3.1.1 Geographical location

The experimental area was situated at 23°77′N latitude and 90°33′E longitude at an altitude of 9 meter above the sea level (Anon., 2004).

3.1.2 Agro-ecological region

The experimental field belongs to the Agro-ecological zone of "The Modhupur Tract", AEZ-28 (Anon., 1988a). This was a region of complex relief and soils developed over the Modhupur clay, where floodplain sediments buried the dissected edges of the Modhupur Tract leaving small hillocks of red soils as 'islands' surrounded by floodplain (Anon., 1988b). The experimental site was shown in the map of AEZ of Bangladesh.

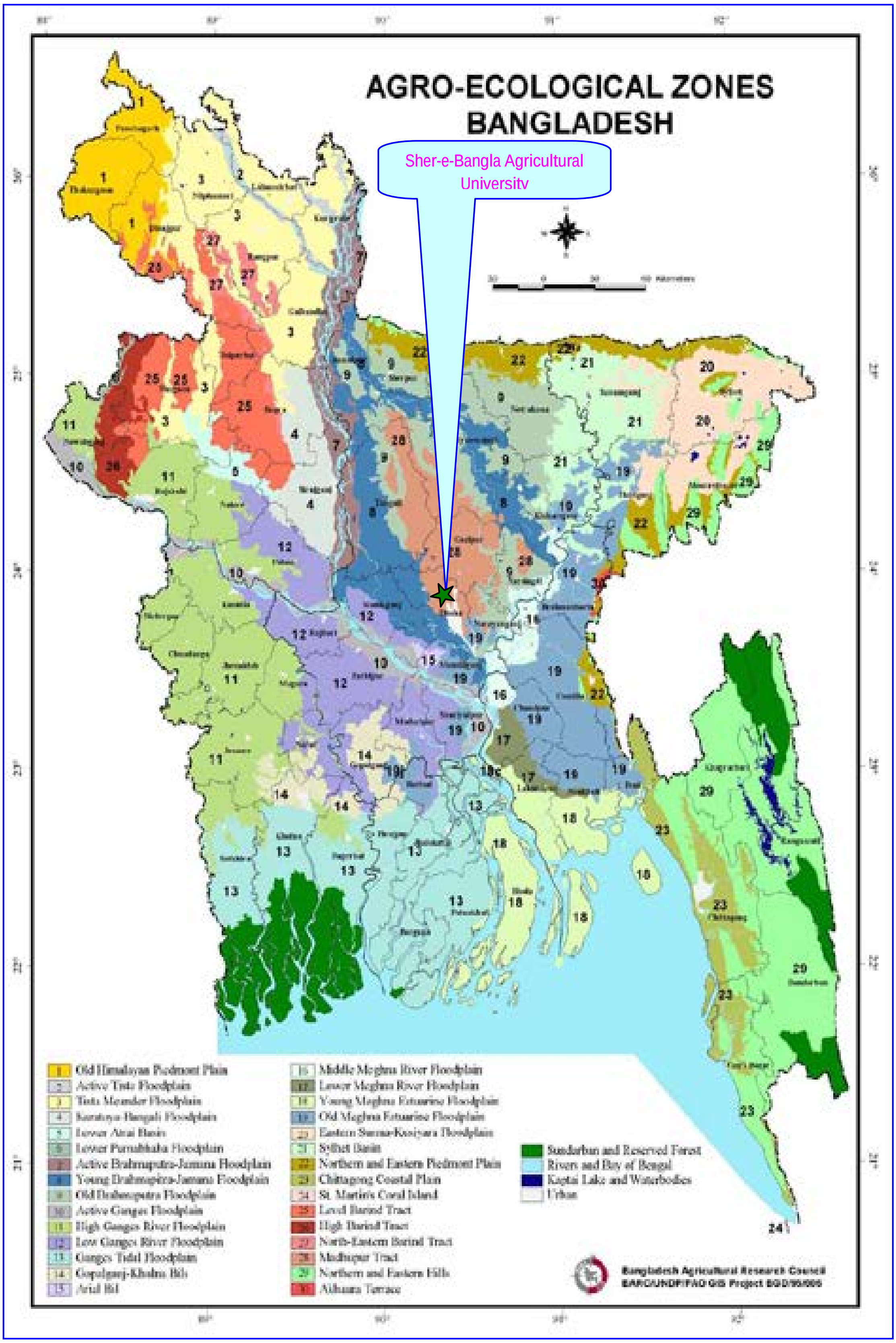

Fig 1: Different Agro-ecological Zones of Bangladesh

3.1.3 Climate

The area has sub tropical climate, characterized by high temperature, high relative humidity and heavy rainfall with occasional gusty winds in Kharif season (April-September) and scanty rainfall associated with moderately low temperature during the Rabi season (October-March). Weather information regarding temperature, relative humidity and rainfall prevailed at the experimental site during the study period were presented in Appendix II.

3.1.4 Soil

The soil of the experimental site belongs to the general soil type, Shallow Red Brown Terrace Soils under Tejgaon Series. Top soils were clay loam in texture, olive-gray with common fine to medium distinct dark yellowish brown mottles. Soil pH ranged from 5.6-6.5 and had organic matter 1.10-1.99%. The experimental area was flat having available irrigation and drainage system and above flood level. Soil samples from 0-15 cm depths were collected from experimental field. The analyses were done by Soil Resource and Development Institute (SRDI), Dhaka. The physico-chemical properties of the soil were presented in Appendix III.

3.2 Materials

Seven different genotypes of mungbean were used for the study. The name and origin of them are presented in Table-1.

Table-1. List of the mungbean genotypes used in the study

Serial No.	Genotypes	Country of origin/source
01.	BD-6881	Bangladesh (BARI)
02.	BD-6893	Bangladesh (BARI)

03.	BD-6894	Bangladesh (BARI)
04.	BD-6901	Bangladesh (BARI)
05.	BD-6906	Bangladesh (BARI)
06.	BD-6921	Bangladesh (BARI)
07.	BD-6922	Bangladesh (BARI)

3.3 Details of the experiment

3.3.1 Land preparation

Land preparation was started in early February with a tractor. Later on, cross ploughing and final preparation of land were dome with a power tiller. All weeds and stubbles were removed manually. Proper laddering was dome to bring the soil to a proper tilth.

3.3.2 Fertilizer dose

The recommended chemical fertilizer dose was 45, 100, 55 and 1 kg/ha of Urea, TSP, MP and BA respectively (Hussain *et. al*., 2006). The specific plot was manured with cowdung @ 10 t/ha. The fertilizers and manures were applied at recommended doses (Table-2).

Table 2: Rates of fertilizers and manure (kg/ha) applied.

Serial No.	Name of the Fertilizers and Manure	Rate (kg/ha)
01.	Urea	50
02.	Triple Super Phosphate (TSP)	75
03.	Muriate of Potash (MP)	35

04.	Cowdung (manure)	10000

The land was uniformly fertilized with TSP, MP and well rotten Cowdung at the time of final land preparation (Alam et al. 1998). One third of urea was applied during the final land preparation. The rest two third of urea are top dressed in two equal splits. One at the vegetative phase (40 DAS) and the other at flowering stage (65 DAS).

3.3.3 Experimental design and layout

The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. The field was divided into two experimental sets. Each experimental set was divided into three blocks then the blocks were further sub-divided into 28 plots where genotypes were randomly assigned. The plot size was 2.5 m with single line. Row to row distance was 30 cm and plant to plant distance was 10 cm. The genotypes were distributed to each plot with each block randomly.

3.3.4 Genotype mixing and experimental sets

All the seven genotypes sown in uniblend and biblend fashions were chosen for a 7X7 diallel cross without reciprocal, or as some called it “mechanical diallel” (Shukla and Singh, 1999). There were 7 uniblends each of one genotype and 21 biblends each comprising of two genotypes in all combinations.

The field was divided into two experimental set (Set I and Set II) for the desired mixing (blend) and inter-genotypic competition. Each experimental set is divided into three blocks then the blocks were further sub-divided into 28 plots. Seven uniblend and 21 biblend treatments were randomly assigned in 28 plots per replicate in both sets. Seeds of uniblend treatments were sown in usual manner in both sets. But for biblends, seeds of two of the genotypes were sown as alternate plant in all the four rows of the plot in Set I (Fig-3); while genotypes of biblend in Set II were sown in alternate rows of all the four rows of the plot (Fig-4).

Set I

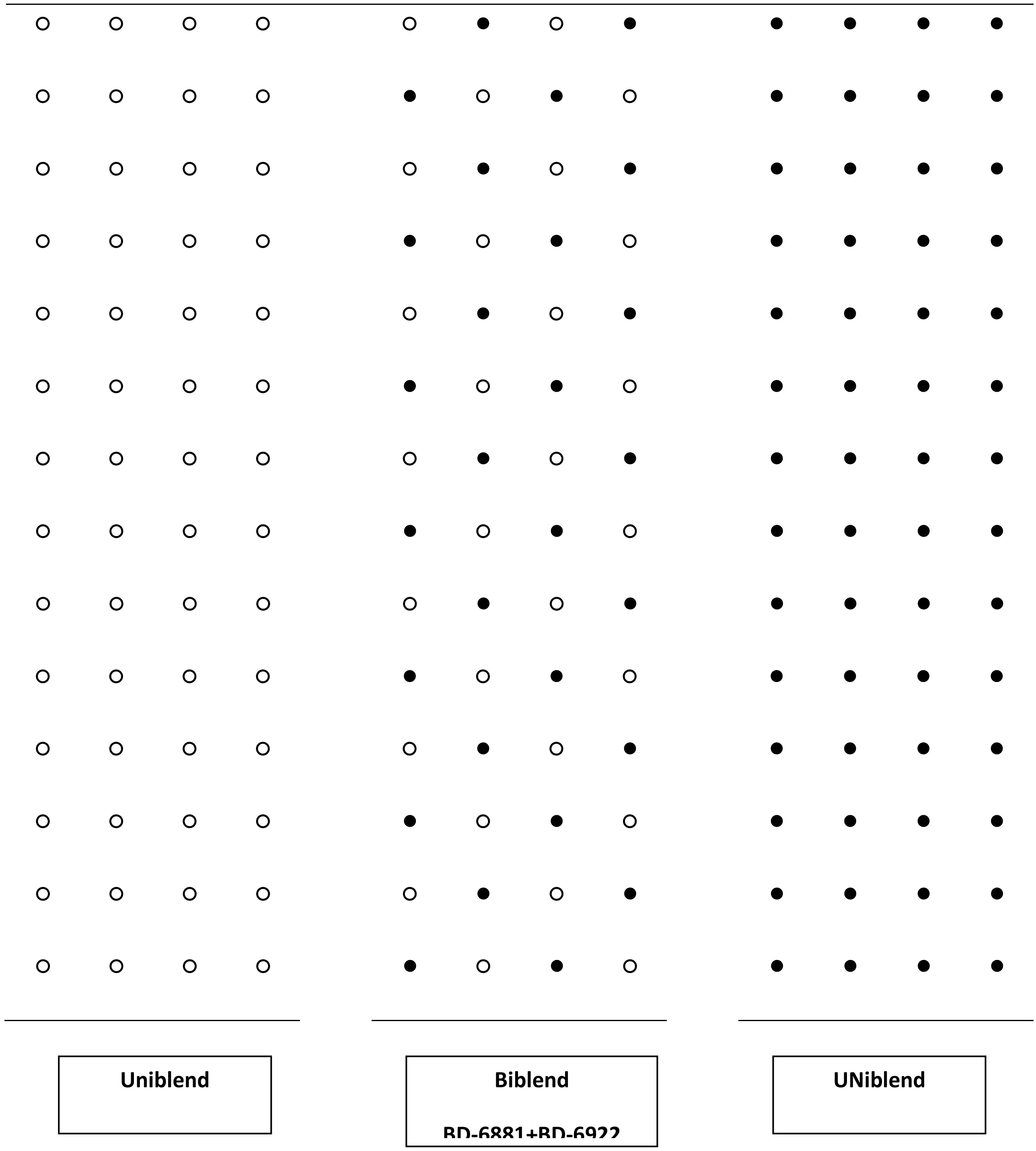

Fig-3: Schematic field plan of uniblend and biblend genotype mixing with example of two mungbean genotypesBD-6881 and BD-6922 in a 4-row plot under experimental Set I (intra row mix).

Set II

○	○	○	○	○	●	○	●	●	●	●	●
○	○	○	○	○	●	○	●	●	●	●	●
○	○	○	○	○	●	○	●	●	●	●	●
○	○	○	○	○	●	○	●	●	●	●	●
○	○	○	○	○	●	○	●	●	●	●	●
○	○	○	○	○	●	○	●	●	●	●	●
○	○	○	○	○	●	○	●	●	●	●	●
○	○	○	○	○	●	○	●	●	●	●	●
○	○	○	○	○	●	○	●	●	●	●	●
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○	○	○	○	○	●	○	●	●	●	●	●
○	○	○	○	○	●	○	●	●	●	●	●
○	○	○	○	○	●	○	●	●	●	●	●

Fig-4: Schematic field plan of uniblend and biblend genotype mixing with example of two mungbean genotypesBD-6881 and BD-6922 in a 4-row plot under experimental Set II (inter row mix).

3.4 Crop management

3.4.1 Seed sowing date

The seeds were sown by hand in 30 cm apart lines at about 5 cm inter-plant distance at about 3 cm depth on 23 March, 2008. Initially excess seeds were sown and later thinned out keeping one plant in each hill.

3.4.2 Intercultural operations

3.4.2.1 Thinning

The plots were thinned out on 15 days after sowing to maintain a uniform plant stand.

3.4.2.2 Weeding

The crop was infested with some weeds during the early stage of crop establishment. Two hand weeding were done, first weeding was done at 15 days after sowing followed by second weeding at 15 days after first weeding.

3.4.2.3 Application of irrigation water

Irrigation water was added to each plot, first irrigation was done as pre sowing and other two were given 2-3 days before weeding.

3.4.2.4 Drainage

There was a heavy rainfall during the experimental period. Drainage channels were properly prepared to easy and quick drained out of excess water.

3.4.2.5 Plant protection measures

The crops were infested by insects and diseases. These were effectively and timely controlled by applying recommended insecticides and fungicides.

3.4.3 Harvesting and post harvest operation

Maturity of crop was determined when 80-90% of the pods became blackish in color. The harvesting was started on 18th June and completed on 20th June, 2008. The variation in harvesting date was due to genotypes and experimental treatments. Ten pre-selected plants per plot from which different yield attributing data were collected and was separately harvested and bundled properly, tagged and then brought to the threshing floor for recording grain and straw yield. Threshing was done using pedal thresher. The grains were cleaned and sun dried to recommended moisture content. Straw was also sun dried properly. Finally grain and straw yields plot^{-1} were determined and converted to ton ha^{-1}.

3.4.4 Recording of data

In both Set I and Set II, ten randomly selected plants from two central rows of a uniblend plot, and twenty randomly selected plants (ten each of two genotypes) of two central rows of a biblend plot, per replicate, were tag-marked and used for recording of data on various characters on individual plant basis. Data on plot basis were recorded from whole plot covering all the rows. Dry weight of plants were collected by harvesting respective number of plants at different specific dates from the inner rows leaving border rows and harvest area for grain. The following data were recorded during the experimentation.

A. Crop growth characters

i. Plant height (cm)
ii. Root length (cm) plant^{-1}
iii. Days to flowering
iv. Days to maturity

B. Yield and other crop characters

i. Number of branches plant^{-1}

ii. Number of pods plant^{-1}
iii. Length of pod
iv. Number of seeds pod^{-1}
v. Weight of 1000-seeds
vi. Seed yield

3.4.5 Detailed procedures of recording data

A brief outline of the data recording procedure followed during the study given below:

A. Crop growth characters

3.4.5.1 Days to 50% flowering

The number of days required for the appearance of 50% flower from the date of sowing.

3.4.5.2 Days to maturity

The number of days required for the maturity from the date of sowing.

3.4.5.3 Plant height (cm)

Plant height was measured from ten selected plants in each plot. The height of the plant was determined by measuring the distance from the soil surface to the tip of the leaf of main shoot.

3.4.5.4 Root length (cm) plant^{-1}

Root length was measured from ten selected plants in each plot at harvest and the mean value was determined.

B. Yield and other crop characters

3.4.5.4 Number of branches plant^{-1}

Branches number was counted from ten pre-selected plants and the mean value was determined.

3.4.5.5 Pods plant^{-1} (No.)

Pods of ten selected plants were counted and the average pods for each plant was determined.

3.4.5.6 Pod length (cm)

Length of ten randomly selected plants measured in cm and mean value was determined.

3.4.5.7 Seeds pod^{-1} (No.)

Pods from each of ten plants per plot were separated from which ten pods were selected randomly. The number of seeds pod^{-1} was counted and average number of seeds pod^{-1} was determined.

3.4.5.8 Weight of 1000-seeds (g)

One thousand cleaned dried seeds were counted randomly from each sample and weighed by using a digital electric balance at the stage the grain retained recommended moisture and the mean weight were expressed in gram.

3.4.5.9 Seed yield (t ha^{-1})

Grain yield was determined from weight of the total sun dried grains of individual plant in gram.

3.4.5.10 Seed yield per plot (kg)

Seed obtained from each unit plot together with those of the sample plants were sun dried and weighed in kilogram.

3.4.6 Statistical analysis

All the collected data were analyzed following the analysis of variance (ANOVA) technique with the help of computer package, MSTAT, Diallel software and with the help of calculator for any supplementary analysis and the mean differences were adjudged by LSD technique (Gomez and Gomez, 1984).

3.4.6.1 Mixing ability analysis

A diallel analysis as outlined by Hallauer and Miranda (1981) was performed. Genotypes (uniblends and biblends) were considered fixed effects. The analysis was similar to Griffing's (1956) Method 2, Model 1 that uses parents and crosses without reciprocals, except that it allows for the partitioning of specific combining ability into variation attributable to (i) among parents and (ii) parents vs. crosses sources. Uniblends and biblends in this study were considered analogous to parents and crosses, respectively, of diallel crosses used in genetic applications. This was justified by the fact that plants from crosses in genetic applications contain equal contributions of both parents, while each biblend in this study contained equal contributions of its two uniblend components.

The plot means were subjected to mixing ability analysis for both Set I and Set II in the same fashion as combing ability analysis of lines in hybrid combination (Schutz and Brim, 1971; Federer et al., 1982; Shukla and Singh, 1999) using method 2, model 1 of Griffing (1956). The detailed analytical methods and procedures with worked examples may be seen in several reference texts (Mather and Jinks, 1987;

Dabholkar, 1992; Falconer and Mackary, 1996, Singh and Chaudhary, 1995; Narian, 1993).

The term general mixing ability (GMA) was used to describe the average performance of a uniblend in biblends, determined on the basis of the performance of biblends having that uniblend as a component. This term is similar in concept to general combining ability used in genetic applications. Similarly, the term specific mixing ability (SMA) was used to describe the deviation in performance of a mixture from that predicted by the GMA of both parents. This term is similar in concept to specific combining ability used in genetic applications.

The general objectives are to compare mixing abilities of the genotypes and to identify better biblend combination(s).

The linear model for the analysis to determine the significance of GMA and SMA effects was:

$$X_{ij} = u + g_i + g_j + s_{ij} + \frac{1}{bc}\sum_{k} \sum_{l} e_{ij}kl$$

X

Where,

ij= 1………p

k=1………b

l=1………c

p= number of genotypes

b= number of blocks

c= number of observation in each plot

X_{ij} is the mean of X_{ij} th genotype over k and l; u is the population mean; $g_i(g_j)$ is the GMA effect. S_{ij} is the SMA effect such that $s_{ij}=s_{ji}$ and $e_{ij}kl$ is the sets effect particular to the ijkl th individual observation.

The restriction imposed are-

$\Sigma_i g_i = 0$ and $\Sigma\ s_{ij} + s_{ii} = 0$ (for each i)

The analysis of variance for mixing ability was carried out using block mean of each entry (mechanical diallel family) as follows

Sources of variation	d.f.	Sum of squares	Mean squares
GMA	n-1	$\frac{1}{n+2}\sum_i (X_{i.}+X_{ii})^2 - \frac{4}{n}X^2_{..}$	MGMA
SMA	n(n-1)	$\sum_i \sum_j X_{ij}^2 - \frac{1}{n+2}\sum (X_{i.}+X_{ii})^2 + \frac{2}{(n+2)(N+2)} Y^2_{..}$	MSMA
Error	(r-1)(t-1)	SSE	MError

Where,

GMA = General mixing ability

SMA = Specific mixing ability

n = Number of genotypes

r = Number of replication

t = Number of treatment

$X_i.$ = Array total of the genotype

X_{ii} = Mean value of the genotype

$X..$ = Grant total of the 1/2n (n-1) mixes and genotypic lines

X_{ij} = Progeny mean values in the mechanical diallel table

SSE = Sum of square due to error (obtained from preliminary ANOVA after dividing by the number of replications).

The GMA and SMA effects of each character may be calculated as follows

$$G = \frac{1}{n+2}\sum (X_{i.}+X_{ii})^2 - \frac{4}{n}X^2..$$

$$S_{ij} = X_{ij} - \frac{1}{n+2}(X_{i.}+X_{ii}+X_{.j}+X_{ij})^2 + \frac{2}{(n+2)(N+2)}Y^2..$$

Standard error (S.E.) of an estimate was calculated as the square root of the variance of concerned estimate e.g. $\sqrt{}$var(g_i) and $\sqrt{}$var(s_{ij}).

$$\text{Var}(g_i) = \frac{(n-1)}{n(n+2)}\sigma^2 e$$

$$\text{Var}(s_{ij}) = \frac{n(n-1)}{(n+1)(n+2)}\sigma^2 e \quad i=j$$

RESULTS AND DISCUSSION

CHAPTER IV

RESULTS AND DISCUSSION

The mean values of different plant characters of individual mungbean genotypes (uniblend) and their mixtures (biblend) under two experimental Sets, as detailed in this section 3.3.4 are presented in Table 3, 4, 5 & 6, respectively. The corresponding analyses of variance for them in are given in Table 7 & 8.

Analysis of variance revealed significant differences among genotypes and their mixtures for all the thirteen characters, such as days to 50% flowering, days to maturity, plant height, root length, branches/plant, pods/plant, seeds/pods, pod length, yield/plant, 1000-seed weight studied under both experimental Sets.

4.1 Analysis of mean performance

4.1.1 Days to 50% flowering

In the experimental Set I, genotype BD-6906 had the minimum mean values for days to 50% flowering (Table 3) and in case Set II it is genotype BD-6894 (Table 5), which indicated most early behavior of flowering. Among the biblend in Set I mixtures BD-6893+BD-6894 and in Set II mixtures BD-6894+BD-6921 showed earliest flowering behavior (Table 4 & 6). The mixture BD-6921+BD-6922 in Set I and BD-6881+BD-6901 in Set II were the latest in both the Sets, reflecting worst mixture for this character.

4.1.2 Days to maturity

The genotype BD-6894 in Set I and genotype BD-6893 in Set II took maximum time for maturity indicating the worse characteristics. On the other hand the genotype BD-6881 had minimum time for maturity in both the Sets (Table 3 & 5), reflecting that best performing genotype for this trait. Among the mixtures in Set I BD-6893+BD-6901 and in Set II BD-6894+BD-6922 holding the lowest mean value showing earliest maturity, but the biblend BD-6906+BD-6922 showed latest maturity in both Sets (Table 4 & 6).

4.1.3 Plant height

Maximum plant height was showed by the genotype BD-6893 in Set I and BD-6901 in Set II, indicating better performing uniblends. The minimum plant height was obtained by genotype BD-6922 in Set I but BD-6881 in Set II. The biblend BD-6901+BD-6922 in Set I and BD-6893+BD-6906 had maximum plant height in both the Sets, reflecting the best biblends mixture for this trait (Table 4 & 6). But in Set I the minimum plant height was shown by BD-6893+BD-6921 and in Set II by BD-6893+BD-6922.

Table 3: Mean values of different characters of seven mungbean genotypes in uniblend in experimental Set I

Treatment	Days to 50% flowering	Days to maturity	Plant height (cm)	Root length (cm)	Branch / plant	Pods/ plant	Pod length (cm)	Seed/ pod	1000-seed weight (g)	Yield/ plant
BD-6881	43.26	64.500	68.900	16.000	3.800	45.000	6.152	**11.960**	28.030	15.126
BD-6893	41.26	70.600	74.580	18.400	2.600	46.200	6.440	**11.480**	40.280	21.364
BD-6894	39.207	77.300	73.000	16.360	3.000	36.200	7.052	**10.360**	25.560	9.586
BD-6901	42.957	74.300	67.220	13.000	2.000	25.800	6.836	**12.080**	34.110	10.631

BD-6906	37.783	66.300	60.200	16.800	2.200	17.600	7.900	**9.920**	21.470	3.780
BD-6921	39.207	64.900	60.260	13.000	2.800	20.600	7.972	**10.280**	27.750	5.877
BD-6922	40.050	74.900	54.200	14.500	5.200	27.200	5.840	**11.360**	28.860	8.611

Table 4: Mean values of different characters of seven mungbean genotypes in biblend mixing in experimental Set I

Treatment	Days to 50% flowering	Days to maturity	Plant height (cm)	Root length (cm)	Branch/ plant	Pods/ plant	Pod length (cm)	Seed/ pod	1000-seed wt (g)	Yield/ plant
BD-6881+ BD-6893	39.813	69.700	66.040	13.200	3.400	35.600	6.176	**11.840**	49.030	20.666
BD-6881+ BD-6894	40.417	68.300	74.300	13.600	2.800	49.400	6.412	**9.840**	33.570	16.318
BD-6881+ BD-6901	39.860	67.600	71.300	16.800	3.400	37.400	6.580	**11.640**	39.420	17.161
BD-6881+ BD-6906	39.127	71.400	70.020	14.800	3.200	46.200	6.864	**12.360**	52.667	22.252
BD-6881+ BD-6921	38.490	69.300	66.200	18.600	2.800	20.600	7.400	**10.120**	33.570	6.998
BD-6881+ BD-6922	37.650	77.300	66.780	16.200	3.200	37.800	6.016	**10.840**	39.430	16.187
BD-6893+ BD-6894	36.447	69.300	63.800	22.400	3.600	27.600	7.640	**10.640**	56.430	16.598
BD-6893+ BD-6901	39.560	64.700	67.920	17.000	3.400	19.000	6.488	9.920	24.480	4.614
BD-6893+ BD-6906	40.783	67.300	75.900	19.200	2.000	37.200	6.516	**11.320**	52.313	22.045

BD-6893+ BD-6921	40.150	76.800	52.200	15.000	3.200	16.400	7.264	**11.000**	29.110	5.246
BD-6893+ BD-6922	38.450	77.800	65.200	25.400	2.400	25.400	6.820	**11.200**	26.147	7.509
BD-6894+ BD-6901	39.483	79.200	54.200	11.800	2.200	33.000	6.720	10.640	26.930	9.396
BD-6894+ BD-6906	36.450	64.800	71.100	19.000	2.600	30.600	7.536	**10.680**	48.127	15.719
BD-6894+ BD-6921	39.417	72.267	52.820	14.800	2.800	16.800	6.888	**8.360**	21.323	3.010
BD-6894+ BD-6922	39.183	68.500	65.800	17.700	0.800	15.400	7.656	**8.960**	26.487	3.659
BD-6901+ BD-6906	37.783	65.900	75.080	21.400	3.000	43.200	6.892	**11.680**	46.753	23.564
BD-6901+ BD-6921	36.983	70.300	66.700	15.800	1.800	28.800	7.104	**11.040**	32.553	10.772
BD-6901+ BD-6922	38.953	75.300	81.900	15.800	3.400	51.800	7.024	**11.240**	75.527	26.465
BD-6906+ BD-6921	39.430	74.300	80.600	20.200	3.000	41.600	6.988	**10.480**	65.527	25.648
BD-6906+ BD-6922	38.560	79.300	67.160	18.300	3.600	35.600	7.144	**11.080**	57.817	22.858
BD-6921+ BD-6922	42.377	69.300	57.400	15.600	1.000	13.000	6.656	8.240	19.110	2.046

Table 5: Mean values of different characters of seven mungbean genotypes in uniblend in experimental Set II

Treatment	Days to 50% flowering	Days to maturity	Plant height (cm)	Root length (cm)	Branch / plant	Pods/ plant	Pod length (cm)	Seed/ pod	1000-seed weight (g)	Yield/ plant
BD-6881	40.330	62.1	47.220	14.4	3.500	42.800	7.187	10.840	27.210	12.624
BD-6893	38.663	73.6	66.180	16.56	2.100	38.600	6.193	11.220	38.280	16.579
BD-6894	35.333	67.1	68.100	14.724	2.800	39.200	6.820	10.573	21.340	9.403
BD-6901	39.000	72.6	71.240	11.7	2.100	29.800	6.503	11.980	36.570	13.056
BD-6906	37.330	64.5	52.300	15.12	2.600	19.400	7.600	8.880	20.720	3.569
BD-6921	36.660	64.6	59.920	11.7	2.400	18.200	7.734	9.240	23.570	3.964
BD-6922	37.660	73	65.400	13.05	5.100	24.600	6.012	12.693	27.920	7.802

Table 6: Mean values of different characters of seven mungbean genotypes in biblend mixing in experimental Set II

Treatment	Days to 50% flowering	Days to maturity	Plant height (cm)	Root length (cm)	Branch/ plant	Pods/ plant	Pod length (cm)	Seed/ pod	1000-seed wt (g)	Yield/ plant
BD-6881+ BD-6893	38.333	71.8	68.400	11.88	3.100	29.800	5.826	11.820	48.670	17.143
BD-6881+ BD-6894	38.997	72.7	66.800	12.24	2.500	47.200	6.512	9.613	34.350	13.425
BD-6881+ BD-6901	40.997	63.6	58.800	15.12	2.900	36.200	6.824	10.460	38.210	15.851
BD-6881+ BD-6906	35.663	76.7	69.400	13.32	3.300	43.400	7.020	13.013	50.260	25.477
BD-6881+ BD-6921	36.660	62.7	84.180	16.74	2.700	21.200	7.238	9.280	31.310	6.160
BD-6881+ BD-6922	37.663	71.5	54.400	14.58	2.700	32.800	6.024	10.840	40.130	14.268
BD-6893+ BD-6894	36.330	60.9	58.280	20.16	3.200	24.200	7.520	10.240	54.410	13.483
BD-6893+ BD-6901	35.997	60.1	55.200	15.3	3.100	16.800	6.681	8.960	25.120	3.781
BD-6893+ BD-6906	37.667	72.5	86.200	17.28	2.500	32.400	6.326	11.200	49.850	18.090

BD-6893+ BD-6921	39.660	76.7	85.600	13.5	2.900	25.600	7.420	12.040	30.080	8.501
BD-6893+ BD-6922	35.660	69.2	49.200	22.86	2.300	27.400	6.258	11.320	27.080	8.399
BD-6894+ BD-6901	39.330	75.5	63.900	10.62	1.400	26.800	6.640	10.640	24.950	7.115
BD-6894+ BD-6906	37.660	58.4	74.080	17.1	2.100	22.200	7.136	11.080	47.570	11.701
BD-6894+ BD-6921	32.997	72.95	64.460	13.32	2.300	19.800	6.161	9.240	19.880	3.243
BD-6894+ BD-6922	35.330	56.6	52.800	15.93	0.700	20.600	7.227	9.920	27.630	5.646
BD-6901+ BD-6906	37.000	60.6	78.200	19.26	2.500	35.400	6.320	11.620	45.820	18.848
BD-6901+ BD-6921	39.660	69.6	57.140	14.22	1.500	24.600	6.157	11.000	34.020	9.206
BD-6901+ BD-6922	37.327	75.8	70.160	14.22	3.100	41.800	6.791	11.240	62.930	28.963
BD-6906+ BD-6921	37.330	67.4	62.400	18.18	2.600	43.200	6.679	11.480	55.240	27.396
BD-6906+ BD-6922	36.660	81.5	80.180	16.47	3.200	29.400	6.909	12.013	58.540	18.381
BD-6921+ BD-6922	37.660	74.1	66.020	14.04	0.900	14.200	6.726	8.360	17.840	2.118

4.1.4 Branches/Plant

In respect of branches/plant, the genotype BD-6922 had maximum no. of branches/plant in both Sets and this genotype was the best performing uniblend for the respective Set. The minimum branches/plant was found from the genotype BD-6901 in Set I and in Set II it was found from the genotype BD-6901 and BD-6893 (Table 3 & 5). The biblend BD-6893+BD-6894 and BD-6906+BD-6922 showed the best performance and had the maximum no. branches/plant (Table 4 & 6). But in Set II the biblend BD-6881+BD-6906 shows best performance. The minimum no. of branches/plant was found from the biblend BD-6893+BD-6922 in both the Sets.

4.1.5 Root length

Root is an important part of plant for uptaking food, nutrition and water. The highest root length was showed by the genotype BD-6893 in both Sets (Table 3 & 5). And minimum root length was showed by the genotype BD-6901 and genotype BD-6921 in both the Sets. The biblend BD-6893+BD-6922 had highest root length in both the Sets (Table 4 & 6).

4.1.6 Pods/ plant

Pods/ plant is one of the main factors influencing yield. The genotype BD-6893 in Set I and BD-6881 in Set II had the maximum pods/plant (Table 3 & 5), performed as a best genotype. The minimum no. of pods/plant was found from the genotype BD-6906 in Set I and genotype BD-6921 in Set II. The biblend BD-6901+BD-6922 in Set I and BD-6881+BD-6894 showed the best performance for this trait (Table 4 & 6). The poorest biblend was found from the mixture BD-6921+BD-6922 in both the Sets.

4.1.7 Pod length

In respect of pod length, the genotype BD-6921 in both Sets had the longest pod (Table 3 & 5). The genotype BD-6922 had the shortest pod. On the other hand, the biblend mixture BD-6894+BD-6922 in Set I and BD-6893+BD-6894 in Set II presenting maximum pod length and performing best (Table 4 & 6). The minimum pod length was found from the biblend mixture BD-6881-BD-6922 in both Sets.

4.1.8 Seeds/ pod

The genotype BD-6901 in Set I and BD-6922 in Set II had the maximum no. of seeds/pod representing as a best performer. The minimum no. of seeds/pod was found from the genotype BD-6906 in both Sets (Table 3 & 5) and found as a coarse performer. Among the biblends, the mixture BD-6881+BD-6906 in both Sets gave the best performance for number of seeds/pod reflecting best genotype (Table 4 & 6). Minimum no. of seeds/pod was found from the genotype BD-6921+BD-6922 in both Sets.

4.1.9 1000 grain weight

The uniblend BD-6893 in both Sets showed maximum 1000-grain weight performing as a best genotype for both Sets for this trait (Table 3 & 5). Whilst the uniblend BD-6906 performed poor in both the Sets. In case of biblend, the biblend mixture BD-6901+BD-6922 in both Sets gave maximum 1000-grain weight, reflecting bold seed size (Table 4 & 6). The biblend mixture BD-6921+BD-6922 in both Sets represents the lowest 1000-grain weight.

Table 7: Analysis of variance for different characters in a 7x7 mechanical diallel population of mungbean in experimental Set I

ITFM	Df	Days to 90% flowering	Days to maturity	Plant height (cm)	Root length	Branch/plant	Pods/plant	Pod length (cm)	Seed/plant	1000-seed weight	Yield/plant
Replication	2	1.35	0.61	1.91	1.03	4.08	0.75	1.71	2.68	7.68	6.54
Treatment	27	3.25	1.73	3.41	2.48	3.41	9.83	2.09	3.28	7.73	4.26
Error	54	0.53	1.27	0.16	0.26	1.17	2.47	2.17	0.00	1.37	7.47

Table 8: Analysis of variance for different characters in a 7x7 mechanical diallel population of mungbean in experimental Set II

ITFM	**Df**	**Days to 90% flowering**	**Days to maturity**	**Plant height (cm)**	**Root length**	**Branch/plant**	**Pods/plant**	**Pod length (cm)**	**Seed/plant**	**1000-seed weight**	**Yield/plant**
Replication	2	1.94	3.70	1.89	1.33	0.29	1.44	6.83	3.59	0.95	0.19
Treatment	27	3.23	1.71	5.58	4.06	4.64	9.09	2.43	2.31	25.90	22.62
Error	54	0.20	0.74	2.74	0.36	3.18	0.27	3.98	0.01	0.55	0.08

4.1.10 Yield/ plant

Yield/plant is an important trait for every crop. In respect of yield/plant the genotype BD-6893 in both Sets performed the best for this trait reflecting best genotype. The minimum yield/plant was found from the uniblend BD-6906 in both the Sets (Table 3 & 5). The biblend mixture BD-6901+BD-6922 in both sets showed the best performance for yield/plant representing the best biblend mixture (Table 4 & 6). The biblend mixture BD-6921+BD-6922 was found as coarse mixture for yield/plant showing poor performance for this trait.

The tendency for mixtures to perform somewhat better than the average of their uniblend components was not uniform. When the yield superiority of mixtures over the average yield of its two component uniblends was regressed on grain yield of biblends, a significant linear relationship was observed (Fig 4 & 6). Biblends tended to perform relatively better than the mean of their component uniblends. Thus, the 1.35% overall average yield increase of biblends over the average of their uniblends components was due to biblend superiority. Only six genotypes in Set I (Fig 5) and seven genotypes in Set II (Fig 7) had the yield of biblends greater than the highest yielding uniblends component.

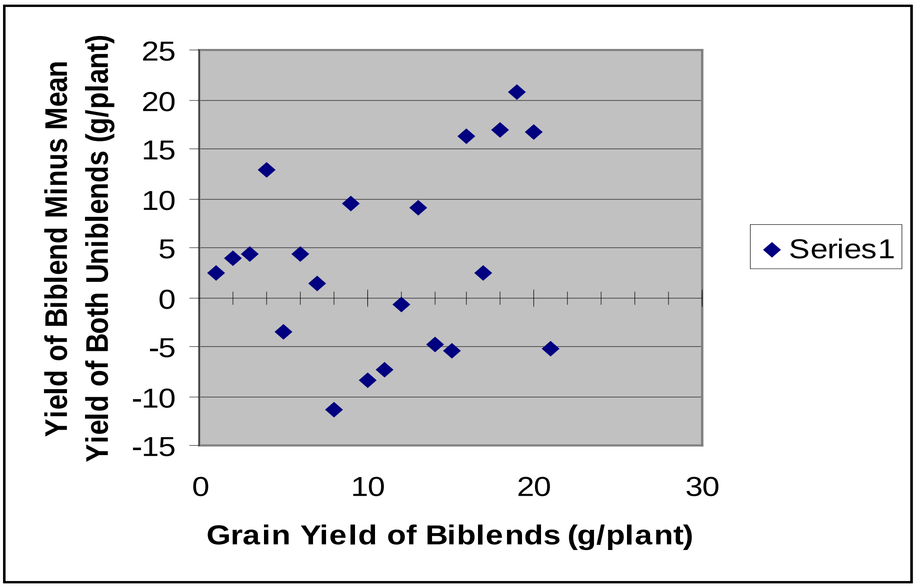

Fig 4: Grain yield advantage of biblends over the mean of both component uniblends for 21 biblends grown in set I

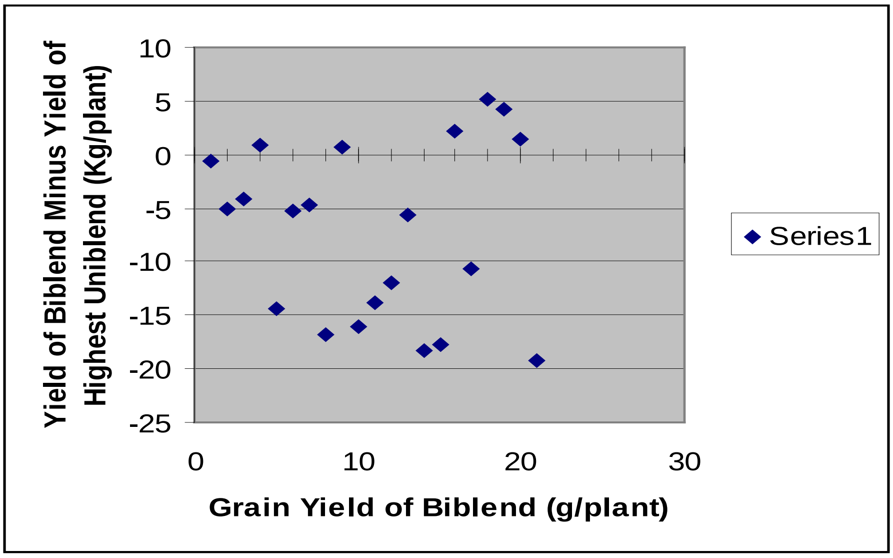

Fig 5: Grain yield advantage of biblends over the highest yielding uniblends for 21 biblends grown in Set I

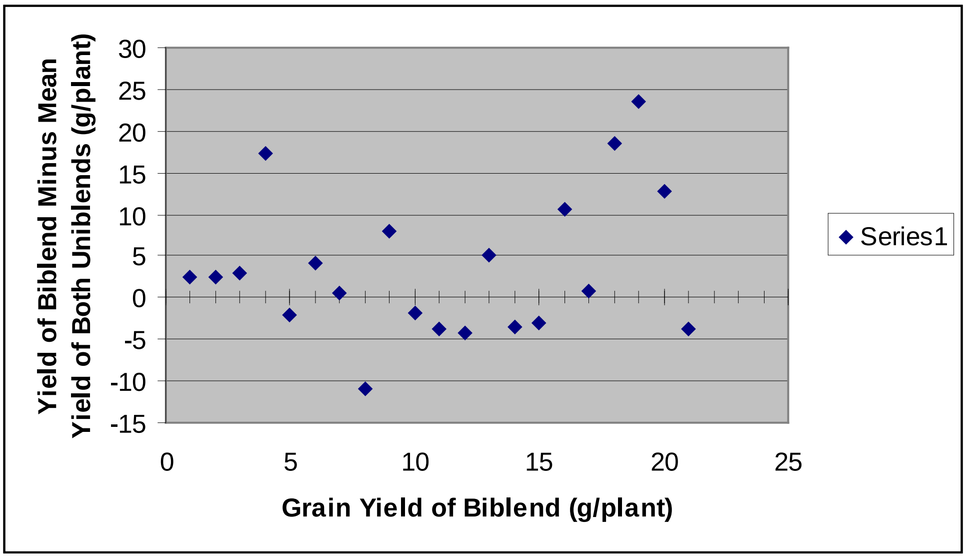

Fig 6: Grain yield advantage of biblends over the mean of both component uniblends for 21 biblends grown in set II

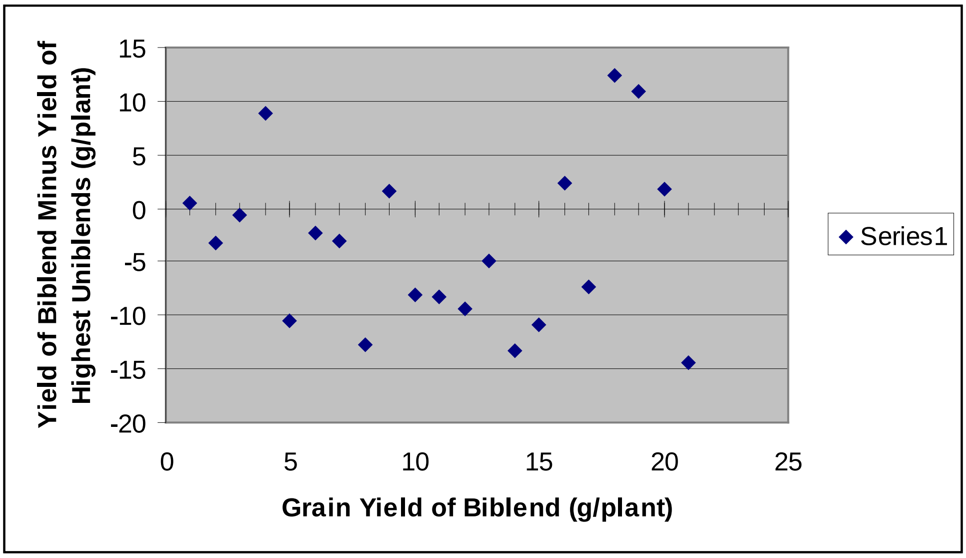

Fig 7: Grain yield advantage of biblends over the highest yielding uniblends for 21 biblends grown in Set II

On overall rating, the study revealed that the genotype BD-6893 showed the best performance for most of the vitally important characters such as pods per plant, seeds/plant, and yield/plant. The genotype BD-6906 was found as a worst genotype for different important yield and yield contributing characters. On the contrary, in respect of biblend mixture, the biblend BD-6901+BD-6922 was found as the best biblend mixture for different characters and biblend mixture BD-6921+BD-6922 performed the poorest for different characters.

4.2 Mixing ability analysis

The detailed results of mixing ability analysis in two experimental Sets may be presented and discussed character wise as follows-

The analysis for variance for mixing ability of a 7x7 uniblends and biblends population for different character in two Sets are presented in Table 9 and Table 10 respectively.

The estimates of general mixing ability (GMA) effects of the seven genotypes and specific mixing ability (SMA) effects of their biblend under both Sets are presented in Table 11 & 12 and Table 13 & 14, respectively.

Based on the GMA effect at the uniblends, the genotypes were classified into three categories:

- Good for highest value of GMA effect
- Poor for lowest value of GMA effects and
- Average for those having GMA effects between highest and lowest values.

Specific mixtures were also classified into same categories in the same ways. The study revealed that the GMA: SMA variance ratio had been more than unity for all the traits studied, suggesting that GMA variance to be more important than SMA variance for the concerned traits.

4.2.1 Days to 50% flowering

Days to 50% flowering exhibited highly significant MS for general and specific mixing abilities in both Sets (Table 9 & 10). The ratio of GMA: SMA effects (>) indicated the predominance of GMA variance components in influencing the trait.

The negative GMA effects for days to 50% flowering are an indicator for desirable genotype for early flowering. The highest significant negative value of BD-6906 (-

0.829) and BD-6894 (-0.888) indicated them as the desirable genotypes for early flowering among the uniblends under two experimental Sets. While the uniblend BD-6881 (0.745) for Set I and BD-6881 (1.074) for Set II was the poor general mixture for this trait (Table 11 & 12).

Results from the study revealed that the estimates of SMA effects in Set I ranged from -2.797 To 2.959 and, in Set II from -3.008 to 2.581 (Table 13 & 14). In Set I, BD-6901 + BD-6921 and in Set II BD-6894 + BD-6921 was good specific mixture and BD-6921 + BD-6922 in Set I and BD-6893 + BD-6921 in Set II was under the category of poor specific mixture. The rest of mixtures were average.

Shukla and Singh (1999) reported that both GMA and SMA variances were important in days to 70% flowering in lentil, which supported the present investigation.

Table 9: Analysis of variance for mixing ability for different characters in a 7X7 mechanical diallel population of mungbean in experimental Set I

Item	df	Days to 50% flowering	Days to maturity	Plant height (cm)	Root length (cm)	Branch/ plant	Pods/ plant	Pod length (cm)	Seed/ pod	1000-seed weight (g)	Yield/ plant
GMA	6	2.73	25.42	60.68	11.66	0.58	194.63	0.70	2.39	148.08	77.06
SMA	21	2.96	21.68	63.35	8.85	0.81	110.82	0.19	0.69	230.09	54.18
GMA:SMA		0.92:1	1.17:1	0.96:1	1.32:1	0.71:1	1.76:1	3.76:1	3.45:1	0.64:1	1.42:1

Table 10: Analysis of variance for mixing ability for different characters in a 7X7 mechanical diallel population of mungbean in experimental Set II

Item	df	Days to 50% flowering	Days to maturity	Plant height (cm)	Root length (cm)	Branch/ plant	Pods/ plant	Pod length (cm)	Seed/ pod	1000-seed weight (g)	Yield/ plant
GMA	6	4.66	20.80	65.72	6.72	0.78	125.16	0.33	1.55	115.14	201.92
SMA	21	2.79	52.54	134.87	8.25	0.85	70.73	0.28	1.09	151.36	147.34
GMA:SMA		1.67 : 1	0.40 : 1	0.49 : 1	0.81 : 1	0.92 : 1	1.77 : 1	1.19 : 1	1.42 : 1	0.76 : 1	1.37 : 1

4.2.2 Days to maturity

ANOVA for mixing ability (Table 9 & 10) shows highly significant mean square due to GMA and SMA in Set I and Set II, suggesting that both GMA and SMA variances were influenced for the days to maturity. The ratio of GMA: SMA mean square (>1) indicated the predominance of GMA component in both experimental Sets.

The estimates of GMA effects ranged from-1.821 to 3.145 in Set I and from -1.585 to 2.558 in Set II (Table 11 & 12). Results from both Sets clearly showed genotypes BD-6881 in Set I and BD-6901 in Set II were the two most desirable genotypes for early maturity; they were thus best general mixer for this trait. On the other hand, the genotype BD-6922 was poor general mixer for early maturity for both the Sets.

For SMA effects, the estimates ranged from 6.899 to -6.655 in Set I and 11.131 to -12.562 in Set II (Table 13 & 14). The biblend BD-6894 + BD-6922 showed the highest significant negative SMA effect in both Set I and Set II. So this was the best specific mixer for early maturity. The biblends BD-6894 + BD-6901 in Set and BD-6906 + BD-6922 in Set II were the worst mixer. The rest of biblends were more or less average specific mixer.

The importance of both GMA and SMA variance components were reported by Shukla and Singh (1999) in lentil for days to maturity.

Table 11: Estimates of general mixing ability effects in 7 uniblends of a 7X7 mechanical diallel population of mungbean in experimental Set I

Treatment	**Days to 50% flowering**	**Days to maturity**	**Plant height (cm)**	**Root length (cm)**	**Branch/ plant**	**Pods/ plant**	**Pod length (cm)**	**Seed/ pod**	**1000-seed weight (g)**
BD-6881	**0.745**	**-1.821**	**1.992**	**-1.030**	**0.419**	**7.253**	**-0.376**	**0.520**	**0.022**
BD-6893	**0.283**	**-0.243**	**0.634**	**1.613**	**0.063**	**0.209**	**-0.150**	**0.333**	**1.614**
BD-6894	**-0.595**	0.886	**-0.720**	**-0.272**	**-0.203**	**-0.723**	**0.202**	**-0.670**	**-4.393**
BD-6901	**0.3741**	**0.289**	**1.892**	**-1.097**	**-0.158**	**1.453**	**-0.072**	**0.493**	**1.149**

BD-6906	**-0.829**	**-1.487**	**2.861**	**1.336**	**-0.092**	**1.987**	**0.289**	**0.173**	**6.955**
BD-6921	**0.010**	-0.769	**-4.229**	**-0.941**	**-0.269**	**-8.146**	**0.345**	**-0.674**	**-5.204**
BD-6922	**0.011**	3.145	-2.429	0.391	0.241	-2.034	-0.237	-0.177	**-0.144**

Table 12: Estimates of general mixing ability effects in 7 uniblends of a 7X7 mechanical diallel population of mungbean in experimental Set II

Treatment	**Days to 50% flowering**	**Days to maturity**	**Plant height (cm)**	**Root length (cm)**	**Branch/ plant**	**Pods/ plant**	**Pod length (cm)**	**Seed/ pod**	**1000-seed weight (g)**
BD-6881	**1.074**	-0.252	**-2.581**	**-1.051**	**0.476**	**7.311**	**-0.049**	**0.126**	**1.794**
BD-6893	**0.185**	1.436	**1.731**	**1.328**	**0.153**	**0.333**	**-0.159**	**0.272**	**3.396**
BD-6894	**-0.888**	-1.580	**-0.348**	**-0.271**	**-0.234**	**0.977**	**0.064**	**-0.409**	**-3.303**
BD-6901	**0.779**	-1.585	**-1.237**	**-0.823**	**-0.401**	**-1.155**	**-0.110**	**0.110**	**-1.367**

BD-6906	**-0.481**	-0.374	**1.111**	**0.806**	**-0.034**	**-0.044**	**0.386**	**0.099**	**5.481**
BD-6921	**-0.519**	-0.202	**4.560**	**-0.313**	**-0.134**	**-3.844**	**0.036**	**-0.563**	**-3.765**
BD-6922	**-0.149**	2.558	-3.235	0.326	0.176	-3.577	-0.168	0.363	-2.235

4.2.3 Plant height

The mixing ability ANOVA showed that both general mixing ability (GMA) and specific mixing ability (SMA) variances were highly significant for plant height in both the experimental Sets (Table 9 & 10). Significant estimates of GMA and SMA variances suggested the importance of both GMA and SMA variances for the trait. General mixing ability of higher magnitude, indicated GMA component to be predominant. This was also clearly demonstrated by the ratio of GMA to SMA variances in both the Sets.

Positive GMA effect is preferable for plant height, GMA effect of all the genotype were significant in both Set I and Set II. The genotype BD-6906 had the maximum positive GMA effect in Set I and BD-6921 in Set II, indicating its best mixing ability. The genotype BD-6893 also appeared to be a good general mixer. On the other hand the genotype BD-6921 in Set I and BD-6922 had the maximum negative GMA effect; it was thus the worst general mixer. The rest of genotypes were average general mixer (Table 11 & 12).

For SMA effect five biblends in Set I and two biblends in Set II out of twenty one, showed significant positive values (Table 13 & 14). Among them BD-6901 + BD-6922 showed maximum significant positive SMA effect in Set I and BD-6893 + BD-6906 showed maximum significant positive SMA effect in Set II, indicating their best specific mixture ability in respective experimental Set. The biblend BD-6894 + BD-6901 in Set I and the biblend BD-6893+BD-6922 in Set II had the maximum negative SMA effect indicating their worst specific mixture ability in respective Set.

4.2.4 Root length

In case of root length positive GMA effect is preferable, GMA effect of all the genotype were significant in both Set I and Set II. The genotype BD-6893 had the maximum positive GMA effect for both the Sets indicating its best mixing ability. The genotype BD-6906 also appeared to be a good general mixer. On the other hand the genotype BD-6901 in Set I and BD-6881 had the maximum negative GMA effect; it was thus the worst general mixer. The rest of genotypes were average general mixer (Table 11 & 12).

For SMA effect five biblends in Set I and two biblends in Set II out of twenty one, showed significant positive values (Table 13 & 14). Among them BD-6901 + BD-6922 showed maximum significant positive SMA effect in Set I and BD-6893 + BD-6906 showed maximum significant positive SMA effect in Set II, indicating their best specific mixture ability in respective experimental Set. The biblend BD-6894 + BD-6901 in Set I and the biblend BD-6893 + BD-6922 in Set II had the maximum negative SMA effect indicating their worst specific mixture ability in respective Set.

Shukla and Sing (1999) reported predominant role of GMA variance component for root length in lentil.

4.2.5 Branches/plant

The analysis of variance for mixture ability (Table 9 & 10) shows both GMA and SMA variances were significant for branches/plant in both the experimental Sets. The magnitude of GMA; SMA ratio indicated the predominant role of GMA part of the variance component in two growing Sets.

From the result of GMA effects, the uniblends BD-6881 and BD-6922 in both the Sets showed significant positive GMA effect (Table 11 & 12). The genotype BD-6881 showed maximum positive GMA effect, indicating it to be the best general mixer in both the Sets. The genotype BD-6922 was also a good general mixer for two Sets. The genotype BD-6921 in Set I and BD-6901 in Set I were the worst general mixer for respective Set. The other genotypes were, on an average, the average general mixers.

For SMA effects, the estimates ranged from 0.911 to -2.067 in Set I and 0.858 to -1.730 in Set II (Table 13 & 14). The SMA effects thus showed differential results in Set I and Set II. The biblend BD-6893 + BD-6894 in Set I and BD-6893 + BD-6901 in Set II were the best specific mixture for respective environment. However the biblend BD-6894 + BD-6922 in both the Set were poor specific mixer and the rest were average specific mixers.

Shukla and Singh (1999) reported that both GMA and SMA variance components were important in primary branches/plant and secondary branches/plan in lentil.

4.2.6 Pods/plant

The analysis of variance for mixture ability (Table 9 & 10) shows both GMA and SMA variances were important for regulation and variation of the character. in both the experimental Sets. The magnitude of GMA; SMA ratio suggested the predominant role of GMA part of the variance component in two growing Sets.

The estimates of GMA effects (table 11 & 12), shows that the GMA effects of nearly all the uniblends BD-6881 and BD-6906 in Set I and BD-6881 and BD-6894 in Set II showed positive GMA effect. The genotype BD-6881 Showed maximum positive GMA effect, indicating it to be the best general mixer in both the Sets. The genotype BD-6921 was the worst general mixer for both Sets. The other genotypes were, on an average, the average general mixers.

Among the biblends mixtures, the estimates ranged from 20.917 to -14.128 in Set I and 18.289 to -11.178 in Set II (Table 13 & 14). The SMA effects thus showed differential results in Set I and Set II. The biblend BD-6901 + BD-6922 In Set I and BD-6906 + BD-6921 In Set II were the best specific mixture for respective environment. However the biblend BD-6893 + BD-6901 in both the Sets were poor specific mixer and the rest were average specific mixers.

Shukla and Singh (1999) reported that both GMA and SMA variance components were important for pods/plant in lentil.

Table 13: Estimates of specific mixing ability effects in 21 biblends of a 7X7 mechanical diallel population of mungbean in experimental Set I

Treatment	Days to 50% flowering	Days to maturity	Plant height (cm)	Root length (cm)	Branch/ plant	Pods/ plant	Pod length (cm)	Seed/ pod	1000-seed weight (g)
BD-6881+ BD-6893	-0.612	0.641	-3.401	-4.193	0.088	-3.328	-0.189	0.251	9.450
BD-6881+ BD-6894	0.870	-1.889	6.215	-1.906	-0.240	11.406	-0.306	-0.744	-0.002
BD-6881+ BD-6901	-0.656	-1.993	0.602	2.118	0.310	-2.772	0.137	-0.109	0.306
BD-6881+ BD-6906	-0.185	3.585	-1.647	-2.315	0.040	5.494	0.059	0.931	7.746
BD-6881+ BD-6921	-1.662	0.767	1.624	3.763	-0.188	-9.972	0.539	-0.460	0.809
BD-6881+ BD-6922	-2.503	4.852	0.404	0.029	-0.299	1.117	-0.262	-0.238	1.609
BD-6893+ BD-6894	-2.638	-2.467	-2.927	4.249	0.911	-3.350	0.696	0.242	21.267
BD-6893+ BD-6901	-0.494	-6.470	-1.421	-0.326	0.678	-14.128	-0.181	-1.642	-16.226
BD-6893+ BD-6906	1.933	-2.926	5.591	-0.559	-0.800	3.537	-0.515	0.078	5.800
BD-6893+ BD-6921	0.460	6.689	-110.18	-2.482	0.589	-7.128	0.177	0.607	-5.243

BD-6893+ BD-6922	-1.242	3.774	0.182	6.585	-0.733	-4.239	0.316	0.309	-13.265
BD-6894+ BD-6901	0.308	6.899	-13.785	-3.639	-0.278	0.806	-0.301	0.082	-7.768
BD-6894+ BD-6906	-1.521	-5.722	2.156	1.127	0.078	-2.128	0.152	0.442	7.622
BD-6894+ BD-6921	0.606	1.026	-9.043	0.795	0.444	-5.794	-0.551	-1.028	-7.011
BD-6894+ BD-6922	0.371	-6.655	2.137	0.771	-2.078	-13.306	0.799	0.926	-6.917
BD-6901+ BD-6906	-1.157	-4.026	3.512	4.352	0.422	8.294	-0.216	0.278	0.705
BD-6901+ BD-6921	-2.798	-0.344	2.224	1.029	-0.601	4.028	-0.060	0.487	-1.335
BD-6901+ BD-6922	-0.829	0.741	15.624	-0.304	0.499	20.917	0.443	0.189	36.576
BD-6906+ BD-6921	0.854	5.433	15.155	2.996	0.533	16.294	-0.539	0.247	25.832
BD-6906+ BD-6922	-0.018	6.519	-0.085	-0.237	0.621	4.183	0.900	0.349	13.063
BD-6921+ BD-6922	2.959	-4.200	-2.754	-0.659	-1.800	-8.283	-0.344	-1.642	-13.484

Table 14: Estimates of specific mixing ability effects in 21 biblends of a 7X7 mechanical diallel population of mungbean in experimental Set II

Treatment	**Days to 50% flowering**	**Days to maturity**	**Plant height (cm)**	**Root length (cm)**	**Branch/ plant**	**Pods/ plant**	**Pod length (cm)**	**Seed/ pod**	**1000-seed weight (g)**
BD-6881**+** BD-6893	-0.339	2.432	4.293	-0.697	-0.019	-6.644	-4.435	0.725	8.329
BD-6881**+** BD-6894	1.398	6.349	4.773	-0.646	-0.231	10.111	-1.595	-0.799	0.709
BD-6881**+** BD-6901	1.731	-2.746	-2.338	0.252	0.336	1.244	1.837	-0.472	2.633
BD-6881**+** BD-6906	-2.343	9.143	5.913	-0.047	0.369	7.333	1.593	2.091	7.834
BD-6881**+** BD-6921	-1.308	-5.029	17.244	0.519	-0.131	-11.067	2.947	-0.979	-1.869
BD-6881**+** BD-6922	-0.674	1.009	-4.740	-0.489	-0.442	0.267	0.147	-0.346	5.421
BD-6893**+** BD-6894	-0.380	7.140	-8.060	0.884	0.792	-5.911	3.945	-0.318	19.167
BD-6893**+** BD-6901	-2.380	-7.935	-10.251	0.219	0.858	-11.178	-0.363	-2.119	-12.059
BD-6893**+** BD-6906	0.550	3.254	18.400	-0.632	-0.108	3.311	-0.012	0.132	5.822
BD-6893**+** BD-6921	2.581	7.282	14.351	0.811	0.392	0.311	-2.673	1.635	-4.701

BD-6893**+** BD-6922	-1.788	2.979	-14.253	-0.146	-0.519	1.844	-.047	-0.012	9.231
BD-6894**+** BD-6901	2.026	10.482	0.529	-0.045	-0.453	-1.822	-3.442	0.245	-5.529
BD-6894**+** BD-6906	1.617	-7.829	8.360	-0.045	-0.119	-7.533	1.408	0.694	10.242
BD-6894**+** BD-6921	-3.008	6.549	-4.709	-0.671	0.181	-6.133	-1.252	-0.483	-8.201
BD-6894**+** BD-6922	-1.045	-12.563	-8.573	0.600	-1.731	-5.600	0.718	-0.729	-1.981
BD-6901**+** BD-6906	-2.380	-9.624	-12.031	0.220	-1.353	-7.000	0.789	-0.986	-11.633
BD-6901**+** BD-6921	-0.672	-5.796	9.920	-0.337	0.547	11.600	5.239	1.377	15.803
BD-6901**+** BD-6922	1.618	0.443	-3.344	-0.295	-0.764	0.533	-0.440	-0.169	2.473
BD-6906**+** BD-6921	0.918	-0.207	-8.229	-0.475	0.281	18.289	2.529	1.247	18.374
BD-6906**+** BD-6922	-0.121	11.132	17.347	0.785	0.569	4.222	0.179	0.854	20.144
BD-6921**+** BD-6922	0.916	3.559	-0.262	0.309	-1.631	-7.178	1.130	-2.136	-11.309

4.2.7 Seeds/pod

For seeds /pods mean square due to GMA & SMA were significant, indicating that both these components were responsible in controlling variation of this trait. It was evident that the GMA:SMA ratio was above one suggesting that GMA effect was predominant.

Highest significant positive GMA effect was obtained in uniblend BD-6881 followed by BD-6901 in Set I and uniblend BD- 6922 followed by BD-6893, suggesting their best general mixing abilities (Table 11 & 12). While the uniblend BD-6921 in both Sets showed the maximum negative GMA effect in respective Set, indicating their poor general mixing abilities. The rest of uniblends were average general mixers.

The SMA effects ranged from 0.931 to -1.642 in Set I and 2.091 to -2.136 in Set II (Table 13 & 14). Out of twenty-one biblends, five biblends in Set I and four biblends in Set II had significant positive SMA effects. Among them the biblends mixer BD-6881+BD-6906 in both Sets had maximum positive significant SMA effect, indicating their best specific mixing abilities for this trait. The biblends BD-6893+BD-6901 in Set I and BD-6921+BD6922 in Set II were poor specific mixers for this trait. The rest of biblends were average specific mixers.

Shukla and Singh (1999) reported that both GMA and SMA variance components were important in primary seed/pod in lentil.

Rroodrigues et al. (1998) in *Phaseolus vulgaris* reported that both GMA and SMA components played role in the variation of seeds per pod.

4.2.8 Pod length

ANOVA (Table 9 & 10) shows general and specific mixing abilities to be highly significant. Which suggested that both GMA and SMA variances were involved in SET I but in Set II only the GMA component was significant and the SMA component non significant, indicating that GMA action was exclusively important in the variation of this trait. The magnitude of GMA: SMA ratio indicated the predominant role of GMA and part of the variance component in both Sets.

From the result of GMA effects, the uniblends BD-6906 and BD-6921 in Set I and BD-6894 and BD-6906 in Set II showed significant positive GMA effect. The genotype BD-6921 in Set I and BD-6906 in Set II showed maximum positive GMA effect (Table 11 & 12), indicating it to be the best general mixer in both the Sets. The genotype BD-6894 was also a good general mixer for two Sets. The genotype BD-6881 in Set I and BD-6922 in Set II was the worst general mixer for respective Set. The other genotypes were, on an average, the average general mixers.

For SMA effects, the estimates ranged from 0.799 to -0.551 in Set I and 0.884 to -0.696 in Set II (Table 13 & 14). The SMA effects thus showed differential results in Set I and Set II. The biblend BD-6906 + BD-6922 in Set I and BD-6901 + BD-6921 in Set II were the best specific mixture for respective environment. However the biblend BD-6894 + BD-6921 in Set I and BD-6881 + BD-6893 in Set II were poor specific mixer and the rest were average specific mixers.

Shukla and Singh (1999) reported that both GMA and SMA variance components were important in primary branches/plant and secondary branches/plant in lentil.

4.2.9 1000-Seed Weight

Mixing ability ANOVA (Table 9 & 10) showed GMA and SMA variances were both important for 1000-seed weight in both experimental mixing Sets. Since the GMA: SMA ratio is more than unity, it suggested that GMA played greater role in controlling the trait in both the mixing Sets.

From the result of GMA effects, the uniblends BD-6906 and BD-6893 in both the Set showed significant positive GMA effect. The genotype BD-6906 Showed maximum positive GMA effect, indicating it to be the best general mixer in both the Sets (Table 11 & 12). The genotype BD-6893 was also a good general mixer for two Sets. The genotype BD-6921were the worst general mixer for both Sets. The other genotypes were, on an average, the average general mixers.

For SMA effects, the estimates ranged from 36.579 to-16.226 in Set I and 20.144 to -12.058 in Set II. The SMA effects thus showed differential results in Set I and Set II. The biblend BD-6901 + BD-6922 in Set I and BD-6906 + BD-6922 in Set II were the best specific mixture for respective environment (Table 13 & 14). However the biblend BD-6893 + BD-6901 in both the Sets were poor specific mixer and the rest were average specific mixers.

Shukla and Singh (1999) reported that both GMA and SMA variance components were important in thousand seed weight in lentil.

4.2.10 Yield/plant

Variances due to GMA and SMA were significant for yield/plant (Table 9 & 10). The analysis clearly demonstrated that both GMA and SMA component played role in the expression of the character. However, GMA component seemed more influential as shown by relatively larger GMA mean square.

The analysis of variance for mixture ability shows both GMA and SMA variances had significant for branches/plant in both the experimental Sets. The magnitude of GMA: SMA ratio indicated the predominant role of GMA part of the variance component in two growing Sets.

From the result of GMA effects, the uniblends BD-6906 and BD-6893 in both the Set showed significant positive GMA effect. The genotype BD-6906 showed maximum positive GMA effect in both Sets (Table 15 & 16), indicating it to be the best general mixer. The genotype BD-6893 was also a good general mixer in both Sets for this trait. The genotype BD-6901 in both the Sets was the worst general mixer for this trait. The other genotypes were, on an average, the average general mixers.

Table 15: General mixing ability (along diagonal) and specific mixing ability (below diagonal) for grain yield for all 15 possible mixtures grown in Set I

	BD-6881	**BD-6893**	**BD-6894**	**BD-6901**	**BD-6906**	**BD-6921**	**BD-6922**
				kg ha^{-1}			
BD-6881	-1.859						
BD-6893	5.012	3.871					
BD-6894	-0.956	0.035	-0.927				
BD-6901	2.819	3.518	-4.129	-3.558			
BD-6906	-12.33	0.422	5.034	1.449	4.598		
BD-6921	-5.529	-10.14	-7.092	-5.59	-7.092	-0.074	

BD-6922	-0.932	0.886	-3.053	-4.072	10.45	11.53	-1.94

Table 16: General mixing ability (along diagonal) and specific mixing ability (below diagonal) for grain yield for all 21 possible mixtures grown in Set II

	BD-6881	**BD-6893**	**BD-6894**	**BD-6901**	**BD-6906**	**BD-6921**	**BD-6922**
				kg ha^{-1}			
BD-6881	-2.079						
BD-6893	3.288	3.078					
BD-6894	0.277	-859	-1.086				
BD-6901	6.259	3.905	-3.999	-3.425			
BD-6906	-10.58	6.066	2.843	-1.206	4.040		
BD-6921	-6.904	-9.867	-3.362	-6.28	-7.783	0.656	

BD-6922	-1.228	0.079	-1.625	-2.037	13.81	6.615	-1.183

The SMA effects thus showed differential results in Set I and Set II. The biblend BD-6921 + BD-6922 in Set I and BD-6906 + BD-6922 in Set II were the best specific mixture for respective environment (Table 15 & 16). However the biblend BD-6881 + BD-6906 in both the Sets were poor specific mixer and the rest were average specific mixers.

Significant difference existed for grain yield among both uniblends and biblends (Table 15 & 16). The average yield of all biblends was also significantly different than the average of all uniblends. Across all biblends, biblends mixtures were about 1.35%, higher yielding than uniblends. This was in agreement with Jensen (1988), and represents a difference of economic consequence that favors the use of mixtures in environments, and with germplasm, similar to the ones tested here. Grain yield in mixtures is influenced by intra-specific competition between component pure lines that begins during early development and continues to physiological maturity. Apparently, complementary relationships among pure lines in mixtures for growth habit, shading, or other factors were responsible for the increased grain yield of mixtures. GMA effects were significant, indicating that some pure lines tended to promote higher yields in mixtures than others. SMA effects were also significant, indicating that the GMA of each combination of pairs of pure lines did not account for the differences in yield observed among mixtures. This differs from results of Shorter and Frey (1979) who found significant GMA but no significant SMA effects in oat.

Plate 1: Photograph of mungbean flower

Plate 2: Some photograph of experimental field

Cont’d

Plate 3: Photograph of pods in plant

Cont'd

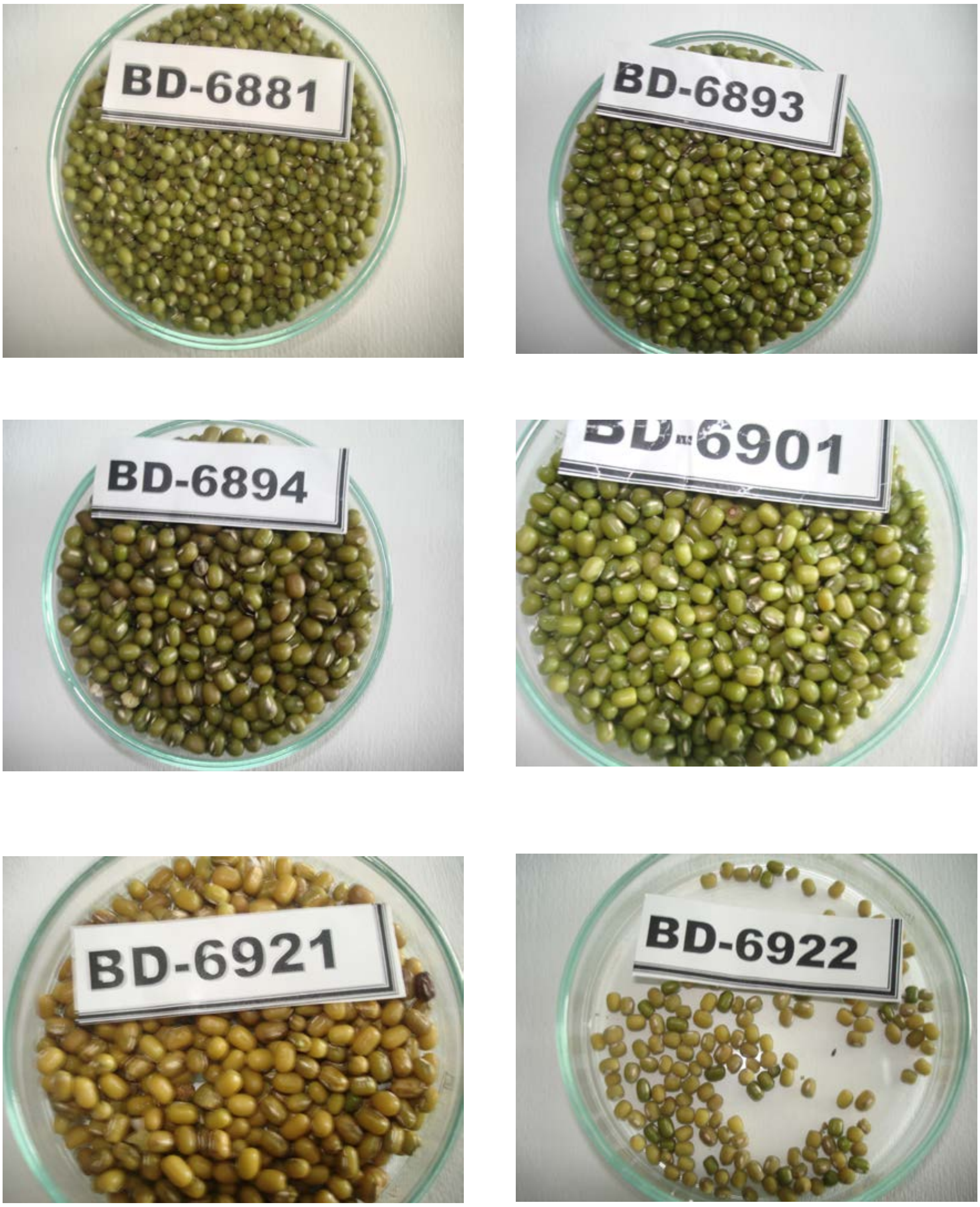

Plate 4: Photograph of seed of some lines of mungbean genotypes

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

CHAPTER V

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

5.1 Summary

Mixing ability analyses of yield and component characters of Mungbean (*Vigna radiata* Wilczek) were carried out in 7x7 mechanical dialled mixtures excluding reciprocals, under two experimental sets, one with intra-row mixing (Set I) and the other with inter-row mixing (Set II) of genotypes in biblend, as well as uniblend stands of them in both sets. Seven genotypes used in the study were BD-6881 BD-6893, BD-6894, BD-6901, BD-6906, BD-6921 and BD-6922. The characters studied were days to 50% flowering, days to maturity, plant height, root length, branches/plant, pod/plant, pod length, seeds/pod, thousand grain weight and yield/plant. The results of the investigation are summarized as follows:

5.1.1 Genotypic mean performance

Of all the 28 mixtures, 7 uniblends and 21 biblends showed significant differences for all the characters under study. Among the uniblends, in the experimental Set I, genotype BD-6906 had the minimum mean values for days to 50% flowering and in case of Set II it was genotype BD-6894. Among the biblend in set I mixtures BD-6893+BD-6894 and BD-6894+BD-6921 in set II showed the earliest flowering behavior.

The genotype BD-6881 took minimum time for maturity in both the sets. Among the mixtures in set I BD-6893+BD-6901 and in set II BD-6894+BD-6922 holding the lowest mean value showing earliest maturity. Maximum plant height was showed by the genotype BD-6893 in set I and BD-6901 in set II. The biblend BD-6901+BD-6922 in set I and BD-6893+BD-6906 had maximum plant height in both the Sets. The highest root length in uniblends was showed by the genotype BD-6893 in both sets. The biblend BD-6893+BD-6922 had highest root length height in both the sets.

In respect of branches/plant, the genotype BD-6893 had maximum no. of branches/plant in Set I; but in Set II BD-6901 had maximum branches. The biblend BD-6901+BD-6922 in Set I and BD-6893+BD-6906 in Set II had maximum no. of branches/plant.

The genotype BD-6893 in set I and BD-6881 in set II had the maximum pods/plant. The biblend BD-6901+BD-6922 in Set I and BD-6881+BD-6894 showed the best performance for this trait. In respect of pod length, the genotype BD-6921 in both sets had the longest pod. The biblend BD-6894+BD-6922 in Set I and BD-6893+BD-6894 in Set II showed maximum pod length.

The genotype BD-6901 in set I and BD-6922 in set II had the maximum no. of seeds/pod. Among the biblends, the mixture BD-6881+BD-6906 in both sets gave the best performance for number of seeds/pod. The uniblend BD-6893 in both sets showed maximum 1000-seed weight. Whilst the biblend BD-6901+BD-6922 in both sets gave maximum 1000-seed weight, reflecting bold seed size. In respect of yield/plant the genotype BD-6893 in both sets performed best for this trait. The mixture BD-6901+BD-6922 in both sets showed the best performance.

5.1.2 Mixing ability studies (Mechanical mixing)

Mixing ability analysis revealed significant GMA and SMA variances for most of the characters studied, suggesting the role of both variances in the control of these characters. The highest significant negative value was found in genotype BD-6906 in Set I and BD-6894 in set II for early flowering among the uniblends under two experimental Sets. In Set I, BD-6901 + BD-6921 and in Set II BD-6894 + BD-6921 was good specific mixture. Results from both Sets clearly showed genotypes BD-6881 in Set I and BD-6901 in Set II were the two

most desirable genotypes for early maturity. The biblend BD-6894 + BD-6922 showed the highest significant negative SMA effect in both Set I and Set II.

In case of plant height the genotype BD-6906 had the maximum positive GMA effect in set I and BD-6921 in set II, indicating its best mixing ability. The biblend BD-6901 + BD-6922 showed maximum significant positive SMA effect in Set I and BD-6893 + BD-6906 showed in set II. In respect of root length the genotype BD-6893 had the maximum positive GMA effect for both the Sets. The biblend BD-6901 + BD-6922 showed maximum significant positive SMA effect in Set I and BD-6893 + BD-6906 in set II.

The genotype BD-6881 showed maximum positive GMA effect in case of branches/plant, indicating it to be the best general mixer in both the sets. The biblend BD-6893 + BD-6894 in Set I and BD-6893 + BD-6901 in Set II were the best specific mixture for respective environment.

For pods/plant BD-6881 and BD-6906 in Set I and BD-6881 and BD-6894 in Set II showed positive GMA effect. Among the biblends mixtures, the biblend BD-6901 + BD-6922 in Set I and BD-6906 + BD-6921 in Set II were the best specific mixture for respective environment. The genotype BD-6921 in set I and BD-6906 in set II Showed maximum positive GMA effect for pod length. The biblend BD-6906 + BD-6922 in Set I and BD-6906 + BD-6922 in Set II were the best specific mixture for respective environment.

For seeds /pods the highest significant positive GMA effect was obtained in uniblend BD-6881 in set I and uniblend BD- 6922, suggesting their best general mixing abilities. The biblends mixer BD-6881+BD-6906 in both sets had maximum positive significant SMA effect. In case of 1000 grain weight, the genotype BD-6906 showed maximum positive GMA effect, indicating it to be the best general mixer in both the sets. The biblend BD-6901 + BD-6922 in Set I and BD-6906 + BD-6922 in Set II were the best specific mixture for respective environment. In respect of yield/plant the genotype BD-6906 showed maximum positive GMA effect in both sets. The biblend BD-6921 + BD-6922 in Set I and BD-6906 + BD-6922 in Set II were the best specific mixture for respective environment.

5.2 Conclusions

Variety blends were somewhat superior in yield and yield contributing traits. Differences in maturity and height were no more important than other genotypic differences in contributing to the better yielding of blends. These results showed an overall yield advantage of 1.35% of mixtures compared with the average yield of their uniblend components. The high correlation of grain yield in biblends and average grain yield of the two component uniblends comprising each biblend indicated that grain yield of biblends could be accurately predicted from information from uniblends.

Cultivar blends in mungbean and other crops were somewhat superior to uniblend cultivars for yield and yield stability. The challenge remains to develop cultivar pairs adapted to growth in mixtures and to identify physiological or phenotypic components that are involved in both positive and negative inter-genotypic interactions in cultivar blends.

The ability to successfully develop superior cultivar blends on the basis of pure-line performance is advantageous to both plant breeders and farmers. For plant breeders, the high correlation of pure-line performance and general blending ability and the lack of cultivar- cultivar interactions simplify and reduce costs of blend breeding procedures. In addition, farmers can successfully select the component cultivars for blending simply by choosing those cultivars best adapted to their region based on cultivar evaluation trial data.

5.3 Recommendations

Results from this investigation clearly show that certain genotypic mixtures (biblend) have substantial advantages over their respective components (uniblend) as well as over the standard genotypes. Therefore, to overcome the problem of low and unstable yield in mungbean, this study can be used in synthesizing mixtures of genotypes provided the commercial product is more or less homogeneous.

Since the farmers, traders and consumers would all prefer uniformity in many characters of cultivars, only synthesis of mixtures of two components with characters similar to in terms of flowering, maturity, pod/plant, seed /plant, yield /plant, and 1000 seed weight need to be considered.

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APPENDICES

APPENDICES

Appendix 1: Basic statistics for ten characters in uniblends of mungbean genotype in set I

Traits	Range	σ^2	σ	Mean
Days to 50% flowering	37.783-43.26	549.56	23.44	48.70
Days to maturity	64.5-77.3	39.29	6.27	9.81
Plant height (cm)	54.2-74.58	56.07	7.49	65.48
Root length (cm)	13.0-18.4	4.09	2.02	15.44
Branches per plant	2-5.2	1.14	1.07	2.94
Pods per plant	17.6-46.2	130.49	11.42	31.23
Pod length (cm)	5.84-7.972	0.68	0.82	6.88
Seeds per pod	9.92-12.08	0.75	0.87	11.06
1000 seed weight (g)	21.47-40.28	37.18	6.10	29.44
Grain yield per plant (g)	3.78-21.364	35.03	5.92	10.70

Appendix 2: Basic statistics for ten characters in uniblends of mungbean genotype in set II

Traits	Range	σ^2	σ	Mean
Days to 50% flowering	35.333-40.33	2.94	1.71	37.28
Days to maturity	62.1-73.6	49.91	7.06	69.09
Plant height (cm)	47.22-71.24	66.98	8.18	67.25
Root length (cm)	11.7-16.56	10.68	3.27	17.27
Branches per plant	2.1-5.1	0.57	0.75	2.45
Pods per plant	18.2-42.8	135.57	11.64	31.54
Pod length (cm)	6.012-7.734	0.20	0.45	6.89
Seeds per pod	8.88-12.693	1.17	1.08	10.62
1000 seed weight (g)	20.72-38.28	281.43	16.78	41.17
Grain yield per plant (g)	3.569-16.579	66.26	8.14	14.22

Appendix 3: Basic statistics for ten characters in biblends of mungbean genotype in set I

Traits	Range	σ^2	σ	Mean
Days to 50% flowering	36.447-42.377	4.44	2.11	37.19
Days to maturity	64.7-79.3	27.50	5.24	70.40
Plant height (cm)	52.2-81.9	77.77	8.82	61.48
Root length (cm)	11.8-25.4	3.32	1.82	13.89
Branches per plant	0.8-3.6	1.21	1.10	3.09
Pods per plant	13-51.8	100.38	10.02	30.37
Pod length (cm)	6.016-7.656	0.52	0.72	6.77
Seeds per pod	8.24-12.36	1.35	1.16	10.68
1000 seed weight (g)	19.11-75.527	49.45	7.03	27.94
Grain yield per plant (g)	2.046-26.465	23.53	4.85	9.57

Appendix 4: Basic statistics for ten characters in biblends of mungbean genotype in set II

Traits	Range	σ^2	σ	Mean
Days to 50% flowering	32.997-40.997	2.44	1.56	36.84
Days to maturity	56.6-81.5	21.97	4.69	71.37
Plant height (cm)	49.2-86.2	123.59	11.12	66.94
Root length (cm)	10.62-22.86	8.65	2.94	15.54
Branches per plant	0.7-3.3	0.63	0.80	2.74
Pods per plant	14.2-47.2	85.67	9.26	29.29
Pod length (cm)	5.826-7.52	0.24	0.49	6.80
Seeds per pod	8.36-13.013	1.40	1.18	10.49
1000 seed weight (g)	17.84-62.93	178.71	13.37	39.23
Grain yield per plant (g)	2.113-28.963	61.24	7.83	13.20

Appendix 5: Monthly maximum, minimum and mean air temperature of the experimental site during the period from January 2008 to June 2008

Month	Year	Monthly average air temperature (^0C)		
		Maximum	**Minimum**	**Mean**
January	2008	24.31	13.65	18.978
February	2008	25.92	14.11	20.015
March	2008	31.59	22.15	26.867
April	2008	34.37	26.06	30.218
May	2008	34.78	24.57	29.675
June	2008	35.40	28.50	31.95

[Source: Bangladesh Meteorological Department, Agargaon, Dhaka]

Appendix 6: Monthly relative humidity, total rainfall and total sunshine of the experimental site during the period from January 2008 to June 2008

Month	**Year**	**Average relative humidity (%)**	**Total rainfall (mm)**	**Total sunshine (hours)**
January	2008	72.90	159	1455.00
February	2008	62.78	170	1827.50
March	2008	59.13	258	1821.00
April	2008	61.51	180	2546.00
May	2008	64.23	616	2359.00
June	2008	68.14	446	1246.00

[Source: Bangladesh Meteorological Department, Agargaon, Dhaka]

Appendix 7: Physical characteristics and chemical composition of soil of the experimental plot.

Soil Characteristics	Analytical results
Agrological Zone	Madhupur Tract
P^H	6.00 – 6.63
Organic matter	0.84
Total N (%)	0.46
Available phosphorous	21 ppm
Exchangeable K	0.41 meq / 100 g soil