MIXING ABILITY AND INTER-GENOTYPIC COMPETITION FROM 7×7 UNIBLENDS AND BIBLENDS OF SOYBEAN GENOTYPES

A Thesis

By

FIROZ MAHMUD

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FIROZ MAHMUD

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Approved as to style and content by:

(Prof. Dr. Md. Ali Newaz)
Supervisor

(Prof. Dr. M. Amirul Islam)
Co-supervisor

(Prof. Dr. Lutful Hassan)
Chairman
Examination Committee and Head
Department of Genetics and Plant Breeding
Bangladesh Agricultural University
Mymensingh

November, 2002

Dedicated to
My

BELOVED PARENTS

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SYMBOLS AND ABBREVIATIONS USED

ANOVA, anova	= Analysis of variance
AVRDC	= Asian Vegetable Research and Development Centre
BARI	= Bangladesh Agricultural Research Institute
BAU	= Bangladesh Agricultural University
cm	= centimeter, centimetre
d.f.	= Degree of freedom
FAO	= Food and Agriculture Organization
Fig.	= figure
G	= gram
GMA, gma	= general mixing ability
Ha	= hectare
Kg	= kilogram
M	= meter,
Me	= mean square due to error
Mg	= mean square due to gma
Ms	= mean square due to sma
MS	= mean square
RCBD	= randomized complete block design
Rep.	= replication
SE	= standard error
SMA, sma	= specific mixing ability
>	= greater than
<	= smaller than

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ABSTRACT

Mixing ability and inter-genotypic competition from 7×7 mechanical diallel mixtures excluding reciprocals of Soybean (*Glycine max* L.) were studied, during November 2001-April 2002, 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 significant differences among the genotypes were found for all the traits examined. The mean performance analysis showed that, the genotype PM–78 had earliness for flowering and maturity, and the biblends PM-78 + Ramsom and BS-3+ BS-16 exhibited earliest flowering and maturity behaviour. The genotype G-2 showed the best performance for pods/plant, seeds/plant, yield/plant, biological yield/plant, and yield/plot.

Variances due to general mixing ability (GMA) and specific mixing ability (SMA) were significant for most of the traits. The predominant role of GMA variances were affirmed in all the characters studied.

The genotype PM-78 was found to be the best general mixer for earliness in flowering and maturity in both experimental sets. 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 the both experimental sets. Whilst the genotype BS-60 was found to be a good general mixer for harvest index in both experiments, as revealed by their respective uniblend stand. The mixture (biblend) BS-60 + BS-16 was earliest in flowering and maturity. 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. For experimental Set I, the biblend BS-3+BS-16 and for experimental Set II the biblend PB-1+BS-16 were the best specific mixers.

CHAPTER I

INTRODUCTION

Soybean [*Glycine max* (L.) Merrill] is an important oil seed and grain legume crop of the world and, a prospective high potential crop in Bangladesh. It belongs to the family leguminosae, sub-family papilionaceae and the genus *Glycine*. Soybean (*Glycine max* L.) is reported to have originated in China (Vavilov, 1951 and Nagata, 1960) with *Glycine ussuriensis* as probable progenitor.

It is a self-pollinated crop. The plant is erect, bushy, leafy, herbaceous with the height varying from one to six feet (Copper, 1976). This crop has a great variation in plant and seed characteristics. Colour of the flower may be white or purple. The stem, leaves and pods in most varieties are covered with numerous hairs. Seed coat colour may be brown, green, black or combination of these colours. The cultivated species of soybean is *Glycine max* (L.) Merrill, which has chromosome number of 2n = 40 (Karpechenko, 1925; Kawaskani, 1930). The crop can be grown in tropical, sub tropical and temperate climates, round the year. Soybean called the "Golden bean" or "Miracle bean" or "Protein hope of future" is now being cultivated and consumed in Bangladesh. Soybean contains higher amounts of both oil and protein than any other legume crops. Soybean seed contains about 40-45% protein and 18-20% oil and provides around 60% of the world supply of vegetable protein and 30%of the oil (Fehr, 1989). Soybean today is recognized as one of the premier agricultural crops of the world (Kaul and Das, 1986). It is also a good source of unsaturated fatty acids, minerals like Ca and P, and vitamins A, B, C and D (Rahman, 1982).

The protein of soybean is called complete protein, because it supplies sufficient amount of various kinds of amino acids required for building and repairing the body tissues. Its food value in heart disease and diabetes is well known. Soybean oil contains about 3% lecithin and a fair amount of fat soluble vitamins. Lecithin is an important constituent of all organs in human body, especially of the nervous tissue, the heart and liver (Krishnamurthy and Shivashankar, 1975).

Internal production of the total oil crops in Bangladesh can meet only one-third of the oil requirement. The shortfall is imported at a cost of about US$ 160 million per year. The major import is of soybean and palm oil. Occasionally crude soybean oil is imported and refined in this country and marketed. Extraction of oil from soybean seed is not yet possible in Bangladesh. Soybean produced locally in our country is mostly used for making nutritious food dishes and confectionary items such as soyadal, soyakhechuri, soyapollao, soybori, soyachatni, soyaparata, soyamilk, soyacakes, soyabiscuits, soyabread, and soon (Mondal and Wahhab, 2001; Khaleque, 1998). The green kernel of soybean may be taken as vegetable and also used in fried rice, 'singara' and curry. Soyamilk is comparable to cow's milk (Smith, 1975). At present local production is also used as the ingredients of animal and poultry feed.

Soybean can play a vital role in balancing the protein-calory malnutrition in Bangladeshi diet. Generally protein and oil contents are negatively correlated, so it is difficult to find a high oil containing crop with high protein content. But total protein plus oil content is higher in soybean, and can be selected for improvement. The statistical information regarding production and area coverage under soybean in Bangladesh is not available in systematic form; it is thought to be of 10,000 hectares with about 12,000 tons of production. Soybean improves the soil by fixing the atmospheric nitrogen through *Rhizobium* bacteria that lives in the nodules. Steward (1966) stated that in a season the plants can fix 94 kg/ha nitrogen in the soil. As a result it is very suitable crop to fit into the cropping systems of Bangladesh (Rahman, 1982). It is reported that the bacteria *Bradyrhizobium japonicum* can fix atmospheric nitrogen (about 300 kg/ha/year) in symbiosis with soybeans (Keser and Li, 1992).

Soybean can be grown under a wide range of climatic and edaphic conditions. With well-adapted cultivars, soybean can be cultivated throughout the year in Bangladesh (Haque, 1976 and Rahman, 1982). In the northern part, it can also be grown in summer without affecting the production of transplant aman rice. Even it can be grown in char and haor areas after receding of flood water with no tillage and minimum inputs. In Bangladesh the yield of soybean is very low compared to other soybean producing countries. This is mainly due to use of low yield potential varieties and poor cultivation technologies such as lack of application of inoculum, fertilizer, etc.

Inoculation increased the soil *Rhizobium* population and nitrogen fixation. It also increased grain and nodule weight by 35-45% (Raychaudhuri *et al.*, 1997). In Brazil, *Bradyrhizobium* inoculum has successfully replaced the use of N-fertilizer (Mendes *et al.*, 2000). A linear relationship was found between the amount of biological N-fixation by the whole soybean plant and the soybean yield (Chien *et al.*, 1993).

Yield in soybean is a complex character and various morphophysiological characters contribute to seed yield. These yield contributing characters are related between 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 or less than optimum results in plant breeding (Bhatt, 1973). While 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 components alone.

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

1.1 Objectives:

The present investigation was carried out on soybean with the following objectives:

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

CHAPTER II
REVIEW OF LITERATURE

An attempt has been made here to briefly review the available literature on soybean and few other crops with particular relevance to this thesis work and crop improvement research.

2.1. Mixing ability in soybean and other crops

Schutz and Brim (1971) analyzed yield data from four soybean (*Glycine max* (L.) Merrill) varieties, six two-component mixtures, and four three-component mixtures to study 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 transgressive 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 pure lines 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 mixtures 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 competitor 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 physiological maturity was 27 days. Most genotypic 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 were 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 concepts of general and specific combining ability in diallel crossing experiments. In diallel crossing experiments, only the total of 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 mixture. Superiority over BP indicated that harvest index, primary branches/plant and seeds pod^{-1} were the most responsive characters in varietal 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 7×7 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 general mixture for most of the characters. Mixture Pant Lentil 406+Lentil Hisar 84-8 was the highest yielding mixture. Although varietal mixtures are not an alternative to pure culture, they neverthless exhibit better performance under stress conditions.

2.2. Bradyrhizobial inoculation and its effect

Bradyrhizobium inoculum used to supply sufficient amount of nitrogen to the legume crop which can reduce the use of nitrogenous fertilizer and the cost of production.

Longeri and Herrera (1972) studied nodulation in soybean in uninoculated plants and reported the absence of indigenous *Rhizobium* in the soil. Balasundaram (1974) stated that effective nodulation through *Rhizobium* inoculation are a basic requirement for successful cultivation of soybean. Bhagara *et al.* (1974) showed that inoculation of soybean with effective strains of *Rhizobium* bacteria produced better nodulation and higher yield. Haque *et al.* (1980) observed that Bragg soybean significantly responded with *Rhizobium* strains in nodulation and yield of the crops. Lin. *et al.* (1983) observed in a field experiment that inoculation of two cultivars of soybean with rhizobial strains increased nodulation and other yield contributing characters.

Haque and Zahiruddin (1988) in a number of field trails during 1980-85studied the response of soybean to *Rhizobium* inoculation and observed no nodulation in the uninoculated plants but well nodulation and higher yield inoculated plants. Joshi *et al.* (1989) stated that inoculation of soybean seed with *Rhizobium* increased the number of nodules, and pods plant^{-1}, 100 seed weight and gave higher yield of 0.97 t ha^{-1} than that of 0.88 t ha^{-1} without inoculation.

Haque and Hashem (1992) reported that inoculation of soybean seeds with *Bradyrhizobium* inoculum gave the highest weight of nodule and dry shoot and stover yield. Dubey *et al.* (1995) reported that of the 11 *Rhizobium* strains, RJDH 1 produced the best nodulation (96.1 nodules plant^{-1}) and seed yield (34.2% higher than control) in soybean. Bhuiyan *et al.* (1995) found that inoculation significantly increased the number of nodule plant^{-1}, dry weight of nodule and shoot, and seed yield compared with no inoculation. Thananusont (1996) in a pot experiment observed that *Rhizobium* inoculum increased nodulation in soybean.

Kulhare, *et al.* (1996) reported that application *Rhizobium* alone or in combination with mycorrhizas and PSB with no fertilizer application insignificantly increased the number of nodule and pod and weight of pod and seed plant^{-1} in soybean *cv.* PK 472. Rani and Kodandaramaiah (1997) reported that seed yield of soybean *cv.* Hardu was increased by inoculation with *Rhizobium japonicum* up to 2.40 t ha^{-1} compared with 1.40 t ha^{-1}. Raychaudhuri *et al.* (1997) observed *Rhizobium* inoculation increased the seed yield by 35-43%. Chatterjee *et al.* (1972) reported from a field trail that inoculation of soybean with *Rhizobium* helped in increasing the seed yield.

Fan *et al.* (1992) showed that inoculation with *Bradyrhizobium japonicum* strains 2178 and 2187 increased dry weight of plant, number of pods, 100 seed weight and seed yield by >10%. The best result was obtained with strain 2178. Inoculation increased N and P contents of plants by 56.7-78.3% and 14.6-19.6% respectively.

Vasilas and Fuhrmann (1993) observed that seed yield of soybean was increased by 31% due to inoculation of soybean seed with *Bradyrhizobium japonicum*. Saxena and Tilak (1975) observed that *Rhizobium* inoculated soybean seeds produced 73% higher yield than uninoculated soybean. Vara *et al.* (1994) obtained the yield of 1293 kg ha^{-1} from the inoculated seeds of Gujrat soybean 1 with *Rhizobium* against the lower yield of 1197 kg ha^{-1} from uninoculation.

Thakur and Hasan (1976) found that inoculation of soybean seed with *Rhizobium* increased the grain yield significantly. Keya *et al.* (1981) observed significant increase in yield of soybean due to inoculation with *Rhizobium* strains at the different agroclimatic zones of Kenya. Dahatonde and Shava (1992) obtained higher seed yield of soybean (2.29 t ha^{-1}) from the inoculated crops compared with 1.97 t ha^{-1} without inoculation.

2.3 Varietal variation, character association and genetic parameters

Saad (1995) conducted a field trial in Egypt with soybeans cultivars Evans, Willim-82, Clark, Crawfork and Colombus, and observed that Clark produced the highest number of branches plant. Colombus produced the highest number of pods $plant^{-1}$ and plant height, and Craford had the highest number of seeds pod^{-1}, seed weight and seed yield.

Mahajan *et al.* (1993) informed that seed yield was positively correlated with eight characters in 51 soybean genotypes grown in India during the kharif of 1990. Seed yield $plant^{-1}$ was correlated ($r = 0.75$) with branches $plant^{-1}$ (0.52), days to 50% flowering (0.48), maturity (0.47), and plant height. Saka *et al.* (1996) observed in eleven soybean genotypes of wide range of seed size that the number of seeds $plant^{-1}$ was negatively correlated with seed size.

Khelker *et al.* (1991) in an investigation in India with two soybeans varities-MACS-13 and Monetta observed that both plant height and seed yield were significantly increased with higher plant densities. In the field experiment, Biswas and Mondal (1986) observed significant different among the five soybean genotypes regarding days to flowering and maturity, plant height, number of pods plant^{-1}, 100 seed weight and seed yield ha^{-1} but there was no significant response in respect of number of seeds and seed yield plant^{-1}. The genotype Pb-1 gave the highest yield while the variety Bragg yielded the least.

Singh *et al.* (1974) observed variability in days to flowering and maturity, plant highest and 1000-seed weight among 15 varieties of soybean. Bossier, Devis and Bragg took 53, 44 and 42 days to flowering and 122, 109 and 116 days to attain maturity having plant highest of 90.2, 73.9 and 78.1 cm with 1000-seed weight of 14.0, 15.5 and 14.1g, respectively. Kovachena (1975) observed variability within 8 varieties of soybean, which was large in respect of number of pods plant^{-1}. Plant height was correlated with number of seeds per plant in four varieties and with yield in all the varieties except Kabul and Pakistani-2.

Lantican (1976) reported that the average number of days to flower, yield, maturity and plant height of the variety Bragg at Laguna, Philippines were 29 days, 1.08 t ha^{-1}, 86 days and 44 cm, 49 days, 0.95 t ha^{-1}, 93 days and 63 cm in Thailand, 17 days, 1.42 t ha^{-1}, 83 days and 19.8 cm in Khmer Republic and 28 days, 0.564 t ha^{-1}, 79 days and 25.7 cm at Selangon, Malaysia.

Singh (1975) observed that variety Brag in 4 years at Patnagar required 120, 121, 104 and 100 days to harvest. The variety Semmes required 121, 121, 106 and 102 days respectively. The nature of requirement to harvest a crop variety clearly indicated the flexibility in expression of a character of soybean over a four years period. Rahman and Haque (1978) found variation in yield and days to maturity in soybean. In three years on the basis of about 26-33 trails of

5 varieties namely Davis, L-74, Brag, Clark and Williams have produced seed yield of about 1660 to 1961 kg ha^{-1}.

Singh *et al.* (1994) observed that seed yield was correlated with eight yield contributing characters in 51 soybean genotypes grown during 1987-88 in India. Seed yield per plant showed high positive association with biological yield plant^{-1}, number of pods plant^{-1}, and days to maturity, and number of pods plant^{-1} showed strong correlation with biological yield plant^{-1}, harvest index and plant height, and plant height showed high positive association with days to maturity.

Rahman *et al.* (1996) reported that pods plant^{-1}, branches plant^{-1} and 100-seed weight showed significant and positive correlation with seed yield, plant height, branches plant^{-1}, and days to maturity with pods plant^{-1} but negative correlation with pod length. The number of pod plant^{-1} and seeds pod^{-1} had highest effect on seed yield. Gopani and Kabaric (1970) found that seed yield in six soybean varieties were positively correlated with stem thickness, number of branches, pods, seeds pod^{-1}, days to flowering and days to pod formation. Chaudhari and Singh (1974) reported that seed yield was negatively correlated with seed size, and number of seeds pod^{-1} was correlated with number of pods plant^{-1}. Das *et al.* (1982) experiment with nine soybean cultivars both in the winter and summer seasons observed higher seed yield, 100-seed weight and pods plant^{-1} in Bragg than any of the others and Lee-74 and Clark-63 followed Bragg with respect to these characters. Sabbe and Delong (1996) in a field trial with 8 soybean cultivars observed that cv. Hutcheson was the highest yielding cultivar.

Mehta *et al.* (2000) studied variability and correlation with 60 diverse genotypes of soybean. Plant height had high genotypic and phenotypic coefficients of variation and, high heritability associated with high genetic advance as percentage of mean indicating the possibility of improving this trait through direct selection. Bhandarkar (1999) observed a high genetic coefficient of variation for plant height in soybean. He reported high heritabiliy and genetic advance.

Archana *et al.* (1999) observed high genotypic coefficient of variation and high heritability estimates accompanied with high genetic advance for plant height in 30 genotypes of soybean (*Glycine max*).

Mehetre *et al.* (1998), Roy and Roquib (1998) and Shrivastava and Shukla (1998) reported that plant height had high genetic coefficient of variation. High heritability accompanied with high genetic advance was also observed for plant height.

Major *et al.* (1996) conducted an experiment with one hundred germplasm of soybean (*Glycine max*) in a randomized block design during 1992-94. They observed that genetic advance was high for plant height. Rajarathinam *et al.* (1996) estimated genetic advance, heritability and genetic variability for 8 yield components by evaluating in 35 genotypes of soybean (*Glycine max*). High estimates of heritability and genetic advance were found for plant height.

Dobhal and Gautam(1995) observed a wide range of variability for plant height. High broad sense heritability coupled with high genetic advance was observed for plant height. Jagtap and Mehetre (1994) studied variability, heritability and genetic advance for 12 quantitative traits in 10 indigenous and exotic varieties of soybean (*Glycine max*). Highest genotypic coefficient of variation was obtained for plant height.

Ghatge and Kadu (1993) observed highest variability for plant height. Estimation for the genotypic and phenotypic coefficients of variation and heritability were highest for plant height. Mahajan *et al.* (1994) reported the presence of substantial variation and high heritability in soybean for plant height.

Biswanatha *et al.* (1975) observed that plant height were highly heritable and controlled by additive gene action. Raut and Patil (1975) studied the phenotypic and genotypic coefficients of variation, heritability and expected genetic advance among 36 varieties of soybean for nine characters. They found that plant height had the highest heritability.

Branches per plant are an important primary yield contributing character. A high genetic coefficient of variation (Bhandarkar, 1999) was observed for primary branches per plant. High heritability was observed for number of branches per plant. Roy and Roquib (1998) noticed that primary branches per plant had high heritability along with high genetic advance.

Sridhara *et al.* (1998) investigated number of branches through number of pods per plant; the trait had significant contribution to seed yield. Rajarathinam *et al.* (1996) recorded heritability, genetic advance and genetic variability for 8 yield components in 35 genotypes of soybean (*Glycine max*). High estimates of heritability and genetic advance were recorded for number of primary branches per plant. Jagtap and Mehetre (1994) estimated variability, heritability and genetic advance for 12 quantitative traits in 10 indigenous and exotic varieties of *Glycine max.* Highest genotypic coefficient of variation obtained for the number of branches on main stem.

Mahajan *et al.* (1994) studied heritability and genetic variance of eight quantitative traits in 51 soybean cultivars grown during dry season of 1990 in India. According to them high genotypic coefficient of variation was observed for branches per plant.

Number of nodes per plant is an important physiological character related to yield. Mehta *et al.* (2000) estimated variability for eleven characters with 60 diverse genotypes of soybean. High genotypic and phenotypic coefficients of variation were observed for number of nodes per plant. They also observed high heritability associated with high genetic advance as percent of mean for number of nodes per plant.

Praneetha and Thamburaj (1997) estimated high genotypic coefficient of variation and heritability for nodes per plant. They suggested that the character could be considered for crop improvement in soybean. Jagtap and Mehetre (1994) estimated variability, heritability and genetic advanced for 12 quantitative traits in 10 indigenous and exotic varieties of *Glycine max.* A number of these traits, as well as number of fruiting nodes per plant showed high heritability coupled with high genetic advance, indicating the presence of additive gene action.

Number of pods per plant is one of the primary yield components of soybean. Variations of this character are invariably studied in connection with yield. In general, the higher is the number of pods the higher is the seed yield. Variation in this trait was observed by several researchers.

Mehta *et al.* (2000) observed number of pods per plant had high genotypic coefficient of variation and phenotypic coefficient of variation. High hetability accompanied with high genetic advance as percentage of mean for number of pods per plant indicated that this may be controlled by additive gene action. Bhandarkar (1999) observed a high coefficient of variation and moderate heritability for mature pods per plant which indicated further scope for improvement in this trait.

Mehetre *et al.* (1998) showed significant variation for pods per plant. High heritability values accompanied by high genotypic coefficient of variation for pods per plant. Roy and Roquib (1998) observed pods per plant and high heritability along with high values of genetic advance. Shrivastava and Shukla (1998) estimated genetic parameters of variation. A significant amount of variability was observed for pods per plant. Pods per plant was a major yield contributing character in soybean. Mehetre *et al.* (1997) investigated on 41 soybean genotypes and showed significant variation for pods per plant. High heritability accompanied by high GCV was observed for pods per plant. Praneetha and Thamburaj (1997) observed high genotypic coefficient of variation and heritability for pod yield per plant. Rajarthinam *et al.* (1996) estimates genetic advance, heritability and genetic variability for 8 yield components in 35 genotypes of soybean (*Glycine max*). High estimates of heritability and genetic advance were recorded for pod number per plant. Dobhal and Gaotam (1995) observed a wide range of variability for pods per plant. High broad sense heritability coupled with high genetic advance was observed for pods per plant.

Singh *et al.* (1995) noticed that the maximum genotypic coefficient of variation occurred for pods per plant. The highest heritability estimate was found for pods per plant.

Jagtap and Mehetre (1994) estimated highest genotypic coefficient of variation for number of pods per plant. Jangale *et al.* (1994) studied 34 genotypes of soybean and showed considerable variation for the 10 characters. Estimates of heritability and genetic gain were also high for number of pods per plant. Mahajan *et al.* (1994) informed on heritability and genetic variance, derived on eight quantitative traits in 51 soybean cultivars. High genotypic coefficient of variation was observed for number of pods per plant. High heritability was recorded for pods per plant. Biswanatha *et al.* (1975) found that the number of pods per plant was highly heritable and controlled by additive gene action. Malhotra (1973) observed that the number of pods per plant had the highest coefficient of genetic variation and predicted genetic advance as a percentage of the mean.

Seeds per pod is an important primary yield component. Normally, higher number of seeds per pod is desirable.

Jangale *et al.* (1994) studied 34 genotypes of soybean (*Glycine max*) and reported that considerable variation exist for the 10 characters including seeds per pod. They estimated high heritability for number of seeds per pod. Malhotra (1973) found significant variabilities in 37 soybean varieties for some characters. He observed highest coefficient of genotypic variation and predicted genetic advance as a percentage of mean with number of seeds per pod.

Days to maturity is most important criteria of any crop. It is influenced by genotypes and various environmental factors. Variation, heritability and genetic advance for days to maturity are usually studied for developing early maturing varieties. Significant genetic variation was found by several workers among different genotypes of soybean.

Bhandarkar (1999) observed high genetic coefficient of variation, heritability and genetic advance as percent of mean for days to maturity, which indicated further scope for improvement in this traits.

Nehru *et al.* (1999) derived heritability from data on 16 yield and quality components in 49 genotypes grown during Kharif 1998. They observed days to maturity had high heritability but low genetic advance. Mehtere *et al.* (1998) conducted an experiment with 41 soybean genotypes in field trials during 1994-96. They showed significant variation for days to maturity. Dobhal and Gautam (1995) conducted an experiment during 1991 and 1992 with 65 lines of soybeans (*Glycine max*). A wide range of variability was observed for days to maturity. Jangale *et al.* (1994) studied 34 genotypes of soybean (*Glycine max*) and showed considerable variation for the 10 characters. They recorded high heritability for days to maturity. Ghatge and Kadu (1993) recorded information on heritability and genetic advance, which was derived from data on 16 yield components in 58 promising genotypes of soybean. Highest variability was observed for days to maturity. Heritability was high for days to 50% flowering followed by days to maturity.

100 seed weight is an important grain character which is directly related to seed yield of soybean. Hundred seed weight which reflects the seed size is also an important component trait. It differs widely from genotype to genotypic and influenced by some factors of production. A good number of research works have been conducted on this character.

Archana *et al.* (1999) studied genetic variability heritability and genetic advance in 30 genotypes of soybean (*Glycine max*). They observed high genotypic coefficient of variation for 100 seed weight. Hundred seed weight showed high heritability estimates accompanied with high genetic advance, indicated that these may be controlled by additive gene action and selection may be effective. Bhandarkar (1999) observed high heritability and genetic advance as percent of mean for 100 seed weight showed the possibilities of improvement of this traits contributing to yield. Nehru *et al.* (1999) observed 100 seed weight had high heritability but low genetic advance.

Mehetre *et al.* (1998) studied 100 seed weight which showed high genetic coefficient of variation. High heritability values accompanied by high genetic advance were also observed for 100 seed weight. Mehetre *et al.* (1997) estimated high heritability accompanied by high GCV for the character 100-grain weight. Major *et al.* (1996) observed high genotypic and phenotypic coefficients of variation for 100 seed weight.

Rajarthinam *et al.* (1996) estimates of genetic variability, heritability and genetic advance for 8 yield components in 35 genotypes of soybean (*Glycine max*). They recorded high heritability and genetic advance for 100 seed weight. Jangale *et al.* (1994) showed considerable variation for the 10 characters in 34 genotypes of soybean (*Glycine max*). They estimated high variability for 100 seed weight.

Harvest index measures the partitioning of photosynthesis to economic yield and is considered as one of the most important physiological yield component (Donald and Hamblin, 1976). Harvest index is the ratio of the grain yield to the biological yield (Donald, 1962) and the biological yield is the total yield of plant material (Donald and Hamblin, 1976). Increased harvest index results increased crop yield, probably because of improved portioning of dry matter to reproductive parts (Paniappan, 1985).

Shrivastava and Shukal (1998) evaluated 9 yield related traits of soybean at Jabalpur during Kharif 1994 and 1995 and the data were used for estimating genetic parameters of variation. Biological yield had high heritability coupled with high genetic advance.

Yield plant^{-1} is a complex trait influenced largely by a number of component characters and factors of production. A good number of reports revealed the existence of variability among different genotypes of soybean.

Mehta *et al.* (2000) studied variability for eleven characters with 60 diverse genotypes of soybean. Seed yield per plant had high genotypes and phenotypic coefficient of variation and indicated the possibility of improving this trait through direct selection. Bhandarkar (1999) observed a high genetic coefficient of variation for yield per plant. Moderate heritability was observed for seed yield per plant.

Mehetre *et al.* (1998) showed significant variation for yield per plant. High heritability values accompanied by high genetic coefficient of variation and high genetics advance were observed for yield per plant. Shrivastava and Shukla (1998) revealed a significant amount of variability for seed yield per plant and had high heritability coupled with high expected genetic advance. Mehetre *et al.* (1997) estimated high heritability accompanied by high genotypic coefficient of variation for yield per plant. Praneetha and Thamburaj (1997) studied variability in vegetable soybean and observed that the yield per plant had high genotypic coefficient of variation and heritability.

Major *et al.* (1996) revealed that genotypic and phenotypic coefficient of variation genetic advanced were high for grain yield.

Rajarathinam *et al.* (1996) estimated genetic advanced, heritability and genetic variability in 35 genotypes of soybean. They recorded high heritability and genetic advanced for seed yield of soybean. Dobhal and Gautam (1995) estimated a wide range of variability for yield per plant; high broad sense heritability coupled with high genetic advanced was observed for yield per plant. Singh *et al.* (1995) observed maximum genotypic coefficient of variation occurred for grain yield per plant.

Mahajan *et al.* (1994) studied heritability and genetic variance using 8 quantitative traits in 51 soybean cultivars grown in India. High genotypic coefficient of variation was observed for yield per plant. Ghatge and Kadu (1993) estimated heritability and genetic variance in data derived from 16 yield components of 58 promising genotypes of soybean. They found highest variability for seed yield per plant. Bays (1976) estimated heritability as lowest for seed yield and relatively high for other traits studied in soybean. Raut and Patil (1995) studied the phenotypic and genotypic coefficient of variation, heritability and expected genetic advanced among 36 varieties of soybean for 9 characters. They found that seed yield per plant had the highest heritability.

Malhotra (1973) observed that seed yield had the highest coefficient of genetic variation and predicted genetic advanced as a percentage of mean. Byth *et al.* (1969) have shown that estimated of heritability were lowest for seed yield and relatively high for plant height, pods per plant, seeds per pod, pod length studied in soybean. Annand and Torrie (1963) reported similar results soybean experimented in different parts of the world. From the reviews above, it is clear that a wide range of variability existed for different morphophysiological characters among different genotypes of soybean and it indicates the scope of utilization of these variability for further breeding programmes.

CHAPTER III
MATERIALS AND METHODS

3.1 Experimental site

The research work projecting the thesis was conducted at the field laboratory of the Department of Genetics and Plant Breeding, Bangladesh Agricultural University (BAU), Mymensingh, during the period from November 2001 to April 2002.

3.2 Soil and agroecological zone

The experimental area is located in a medium high land belonging to the Old Brahmaputra Floodplain-Agroecological Zone: 9 (UNDP and FAO, 1988). The soil was sandy loam in texture with pH value of 6.5 (Anonymous, 1979).

3.3 Climate

The location is under a sub-tropical climate, characterized by relatively high temperature and high rainfall from April to October (Kharif) and, low temperature and low rainfall from November to March (Rabi). The relative humidity remains high during the major part of the year except the Rabi season. The weather data recorded at the experimental area during the period of study are provided in Appendix-1.

3.4 Materials

Seven genotypes of soybean were chosen for the study. The name and origin of them are presented in Table 1.

Table 1. List of the soybean genotypes used in the study

SL. No.	Genotypes	Country of origin/source
1	PB-1	India
2	G-2	Taiwan (AVRDC)
3	BS-60	Bangladesh (BCSRP)
4	BS-3	Bangladesh (BCSRP)
5	PM-78	Bangladesh (BCSRP)
6	BS-16	Bangladesh (BCSRP)
7	RAMSOM	Bangladesh (BARI)

3.5 Methods

3.5.1 Land preparation

Land preparation was started in early November with a tractor. Later on, cross ploughing and final preparation of land were done with a power tiller. All weeds and stubbles were removed manually. Proper laddering was done to bring the soil to a proper tilth. The fertilizers and manures were applied at recommended doses (Table 2).

Table 2. Rates of fertilizers and manure (kg/ha) applied, in the study

Name of the fertilizers and manure	Rate(kg/ha)
Rhizobium inoculant	25 g/kg seed
Urea	60
Triple Super Phosphate (TSP)	150
Muriate of potash (MP)	70
Cowdung (manure)	5000

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 in two equal splits as top dress, one at the vegetative phase (40 DAS) and the other at flowering stage (65 DAS). Seeds were inoculated with Bradyrhizobial inoculum, @ 25 g/kg seed, before sowing. This was to facilitate biological nitrogen fixation of growing plants through symbiosis at root zones.

3.5.2 Experimental design

The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. The individual plot size was 2.5m x 1.2m with 4 rows which were 0.3 m apart and 2.5 meter long.

3.5.3 Genotype mixing and experimental sets

Seven genotypes sown in uniblend and biblend fashions were likened for a 7×7 diallel cross without reciprocal, or "mechanical diallel" as some called it (Shukla and Singh, 1999). There were thus 7 uniblends each for one genotype, and 21 biblends each comprising of two genotypes in all combinations.

Two experimental sets (Set I and Set II) were used to provide for the desired mixing (blend) and inter-genotypic competition. Seven uniblend and 21 biblend treatments were randomly assigned with 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 uniformly mixed with equal numbers and sown in all the four rows of the plot in Set I; while genotypes of biblend in Set II were sown in alternate rows of the plot without actually mechanically mixing them (Fig. 1).

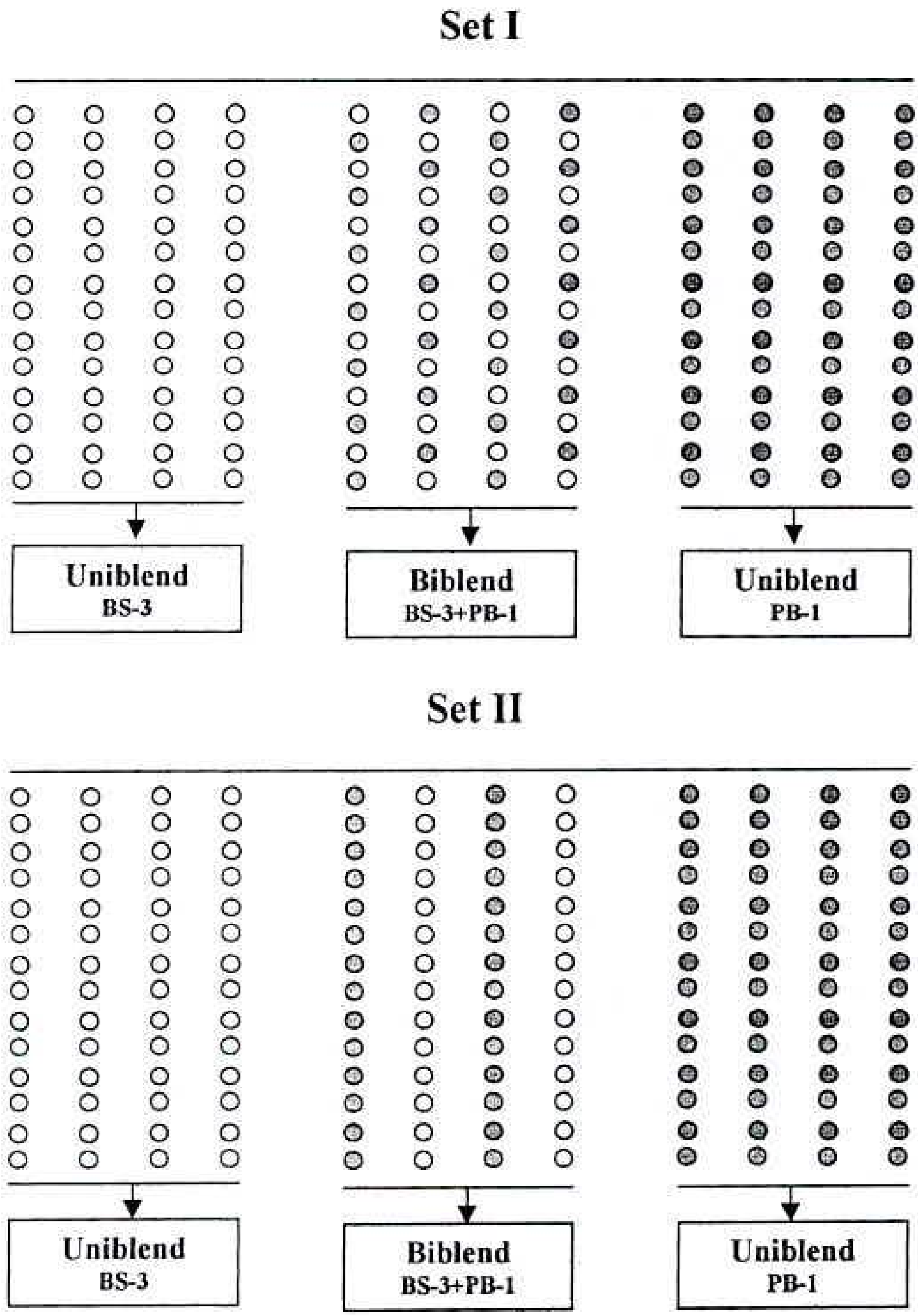

Fig. 1. Schematic field plan of uniblend and biblend genotype mixing with example of two soybean genotypes BS-3 and PB-1 in a 4-row plot under two experimental sets, Set I (intra row mix) and Set II (inter row mix).

3.5.4 Sowing date

The seeds were sown on the 22nd November 2001 according to genotype mixing and experimental plant. Initially excess seeds were sown and later thinned out keeping about 5 cm interplant distance in rows.

3.5.5 Intercultural operation

Thinning was done 15 days after sowing. Two times weeding was done, one after 20 days of sowing seeds and the other after 40 days of sowing. In raising the experimental crop, one irrigation was applied. There was a minor infestations of soybean hairy caterpillars, which were however mechanically control (hand picking).

3.5.6 Harvesting and post-harvest processing

The plants were harvested at full maturity which came with yellowing of leaves and with completion of shedding and when the pod color turned dark brown. Harvesting was begun on 11 March, and completed on 30 April, 2002. The variation in harvesting date was due to genotypes and experimental treatments.

3.5.7 Data collection

In both Set I and Set II, ten randomly selected plants from two central rows of a uniblend plot, and twenty randomly selected plans- ten each- 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 four rows.

The specific criteria used for different characters are as follows:

Plant height (cm): The plant height was taken in cm from ground level to the tip of the main stem from random plant sample as stated above.

Branches per plant: Recorded as number of primary branches from randomly selected plants and averaged.

Days to 1st flowering: The number of days required for the appearance of first flower from the date of sowing.

Pods per plant: Number of both fertile and empty pods from randomly selected plants and averaged.

Pod length (cm): Measured in cm from twenty pods from randomly selected plants and averaged.

Seeds per pods: Counted from twenty pods taken from randomly selected plants and averaged.

100-seed weight (g): One hundred dried seeds were randomly taken from seed lot of each plot and weighed in gram by an electrical balance.

Days to maturity: Recorded in days from date of sowing to date when most of the plants of the plot were ready for harvest.

Yield per plant (g): Weight of the total sun dried grains of individual plant in gram, taken from randomly selected plants and averaged.

Biological yield per plant (g): Biological yield per plant was calculated by adding stover yield with seed yield in gram, from randomly selected plants and averaged.

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.

Harvest index: Estimated as the ratio of per plant economic yield to biological yield as shown below (Gardner *et. al.*, 1985):

$$\text{Harvest index} = \frac{\text{Grain yield plant}^{-1}}{\text{Biological yield plant}^{-1}} \times 100$$

3.5.8 Data analysis

The collected data were analyzed statistically with the help of computer package, MSTAT and with the help of portable calculator for any supplementary analysis following standard texts.

3.5.8.1 Mixing ability analysis

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

The mathematical model was as assumed for the combining ability analysis:

$$X_{ij} = u + g_i + g_j + s_{ij} + \frac{1}{bc}\sum_k \sum_l e_{ij}kl$$

Where,

$ij = 1 \ldots\ldots\ldots p$

$k = 1 \ldots\ldots\ldots b$

$L = 1 \ldots\ldots\ldots c$

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 ijklth 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:

Item	d.f.	Sum of squares	Mean squares
gma	n-1	$\frac{1}{n+2}\sum_i (X_{i.} + X_{ii})^2 - \frac{4}{n} X^2_{..}$	Mg
sma	n(n-1)/2	$\sum_i \sum_j X_{ij}^2 - \frac{1}{n+2}\Sigma(X_{i.} + X_{ii})^2 + \frac{2}{(n+1)(N+2)}.Y^2_{..}$	Ms
error	(r-1)(t-1)	SSE	Me

Where,

gma= general mixing ability

sma= specific mixing ability

n= number of genotypes

r= number of replication

t= number of replication

$X_{i.}$= 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:

$$G_I = \frac{1}{(n+2)} \Sigma(X_{i.} + X_{ii}) - \frac{2}{n} X_{..}$$

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

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

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

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

CHAPTER IV
RESULTS AND DISCUSSION

The mean values of different plant characters of individual soybean genotypes (uniblend) and their mixtures (biblend) under two experimental sets, as detailed in section 3.5.3, are presented in Table 3 & 4, respectively. The corresponding analysis of variance for them in are given in Table 5 & 6.

Analysis of variance revealed significant differences among genotypes and their mixtures for all the thirteen characters, such as days to 90% flowering, days to maturity, plant height, branches/plant, pods/plant, seeds/5-pods, seeds/plant, pod length, yield/plant, biological yield/plant, yield/plot, 100-seed weight and harvest index (%) studied under both experimental sets.

4.1. Analysis of mean performance

In both the experimental sets, genotype PM-78 had the minimum mean values for days to 90% flowering, which indicated its most early behaviour of flowering. Among the biblend mixtures, PM-78 + Ramsom showed earliest flowering behaviour and the mixture G-2 + BS-16 the latest in both the sets.

The genotype BS-16 took maximum time for maturity, on the other hand the genotype PM-78 had minimum time for maturity in both sets. Among the mixtures BS-3 + BS-16 showed earliest maturity, but the biblend PM-78+ Ramsom showed latest maturity in both sets.

Maximum plant height was showed by the genotype BS-16 and the minimum by genotype PB-1 in both sets. The biblend G-2 + BS-16 had maximum plant height in both the sets. But in Set I the minimum plant height was shown by BS-3 + Ramson and in Set II by PB-1 + BS-3.

Table 3. Mean values of different characters of seven soybean genotypes in uniblend and biblend mixing in experimental Set I

Treatment	Days to 90% Flowering	Days to Maturity	Plant height (cm)	Branch/ plant	Pods Per Plant	Seeds/ 5-pods	Seeds/ plant	Pod Length (cm)	Yield/ plant (g)	Biological yield/plant (g)	Yield/ Plot (kg)	100-Seed weight (g)	Harvest Index (%)
Uniblend:													
PB-1	67.33	136.33	30.37	1.100	9.733	7.800	11.267	3.100	1.200	8.267	0.237	10.30	14.35
G-2	77.67	132.67	71.83	3.767	58.90	14.43	118.30	3.233	8.367	19.00	1.673	7.000	43.63
BS-60	76.33	133.33	45.30	2.800	43.40	12.83	86.933	3.567	7.867	17.20	1.573	8.400	45.69
BS-3	74.00	134.00	40.40	2.333	24.83	12.53	46.533	4.287	5.500	11.50	1.100	12.53	48.01
PM-78	55.67	112.33	42.13	1.400	20.20	8.933	25.667	3.133	2.967	8.833	0.597	12.00	34.53
BS-16	84.33	146.67	79.50	4.700	37.93	11.23	63.467	3.533	6.933	16.60	1.387	10.93	41.77
Ramsom	57.00	113.00	37.43	1.233	20.53	8.833	25.567	3.433	2.967	10.03	0.593	12.87	29.40
Biblend:													
PB-1+G-2	72.00	130.33	55.60	3.300	50.60	12.77	110.27	4.133	8.700	19.37	1.740	8.500	45.07
PB-1+BS-60	70.67	135.00	37.90	2.733	43.87	13.07	93.700	4.040	7.400	16.60	1.480	10.73	44.67
PB-1+BS-3	71.33	134.33	34.79	2.863	19.09	10.97	33.333	4.067	4.467	10.90	0.900	12.90	41.10
PB-1+PM-78	60.33	126.00	39.35	1.100	15.11	8.433	20.033	3.167	2.267	8.037	0.457	11.56	28.53
PB-1+BS-16	75.33	139.33	51.47	3.967	38.17	11.47	67.733	3.467	7.033	17.06	1.407	9.390	41.43
PB-1+ Ramsom	63.33	124.33	44.90	1.700	26.73	9.167	41.133	3.337	3.533	10.13	0.713	9.400	35.76
G-2 +BS-60	74.33	133.33	50.01	2.300	26.43	13.23	67.433	3.700	5.787	13.07	1.157	8.357	44.67
G-2+BS-3	76.33	137.33	49.08	2.833	34.43	12.07	74.433	3.933	5.667	12.13	1.133	10.55	46.77
G-2+PM-78	63.33	119.67	64.58	2.233	30.87	12.37	53.700	3.300	3.967	10.27	0.797	7.453	38.97
G-2+BS-16	81.33	137.33	82.30	4.200	49.00	12.17	87.433	3.533	6.867	18.33	1.373	8.200	37.50
G-2+ Ramsom	66.00	125.33	65.90	2.367	43.33	13.23	85.533	3.467	6.067	14.23	1.213	7.233	42.10
BS-60+BS-3	72.33	130.67	41.03	2.967	22.90	12.87	47.033	4.233	5.433	10.63	1.087	13.07	51.23
BS-60+PM-78	66.33	126.33	42.89	2.133	37.57	12.27	65.867	3.733	6.900	14.85	1.380	9.840	46.57
BS-60+BS-16	75.00	134.67	55.13	4.267	46.87	12.33	80.133	3.633	8.000	19.07	1.600	9.800	42.43
BS-60+ Ramsom	66.33	121.67	43.97	2.700	41.97	12.70	85.900	3.600	7.200	16.20	1.440	8.900	44.73
BS-3+PM-78	57.33	123.33	41.48	1.933	23.13	9.667	37.377	3.300	3.933	11.50	0.773	11.63	34.29
BS-3+BS-16	80.33	139.67	75.87	5.333	67.18	14.00	117.27	3.633	12.967	28.93	2.593	11.03	45.27
BS-3+ Ramsom	66.33	121.67	41.77	3.400	33.17	12.97	63.500	3.993	7.000	14.90	1.400	11.00	47.07
PM-78+BS-16	67.67	135.33	61.63	3.633	35.43	10.57	50.250	3.433	5.200	14.33	1.040	10.17	35.87
PM-78+ Ramsom	55.67	113.33	46.23	1.800	13.43	7.433	15.037	3.033	1.633	6.667	0.330	11.20	26.58
BS-16+ Ramsom	69.00	129.33	53.60	4.067	36.04	10.73	52.800	3.533	7.000	15.20	1.500	11.13	46.03
SE(±)	0.545	0.486	2.467	0.318	3.749	0.579	7.7559	0.1348	0.6232	1.548	0.128	0.408	2.533

Table 4. Mean values of different characters of soybean genotypes in uniblend and biblend mixing in experimental Set II

Treatment	Days to 90% Flowering	Days to Maturity	Plant height (cm)	Branch /plant	Pods per Plant	Seeds/ 5pods	Seeds/ plant	Pod Length (cm)	Yield/ plant (g)	Biological yield/plant (g)	Yield/ Plot (kg)	100-Seed weight (g)	Harvest Index (%)
Uniblend:													
PB-1	66.33	136.67	28.59	1.767	13.97	7.300	11.30	3.113	1.233	7.567	0.247	11.20	16.38
G-2	77.67	127.67	73.63	3.600	61.20	13.17	92.40	3.433	6.233	18.07	1.247	6.597	34.44
BS-60	76.33	132.33	44.63	4.833	42.53	12.27	77.10	3.800	8.333	16.02	1.657	10.51	51.88
BS-3	73.00	134.00	42.33	4.000	33.47	13.03	73.07	3.567	6.900	13.43	1.380	11.61	51.21
PM-78	54.33	112.00	40.07	2.567	31.56	8.333	72.21	3.200	3.600	14.27	0.720	13.63	26.01
BS-16	83.67	146.33	85.40	3.933	57.93	10.67	82.27	3.433	11.27	26.00	2.260	13.66	43.49
Ramsom	57.00	112.67	41.78	2.467	26.42	8.167	27.93	3.100	3.000	12.83	0.600	11.22	23.45
Biblend:													
PB-1+G-2	71.33	132.33	53.23	3.000	34.37	9.110	59.07	3.400	3.867	11.27	0.777	6.673	34.09
PB-1+BS-60	71.67	136.33	40.74	2.933	30.39	11.43	55.70	3.967	6.213	13.43	1.243	11.33	45.00
PB-1+BS-3	72.00	135.67	36.15	1.967	17.36	9.833	27.30	3.567	3.763	12.00	0.757	13.65	31.26
PB-1+PM-78	61.67	125.33	39.09	1.967	23.39	8.957	78.16	3.317	3.500	11.24	0.700	12.89	30.92
PB-1+BS-16	75.33	140.67	54.92	4.167	46.83	10.83	76.69	3.233	8.700	20.94	1.740	13.74	41.45
PB-1+ Ramsom	61.33	124.67	36.78	2.233	23.41	7.867	27.40	3.070	2.823	12.34	0.567	10.40	32.96
G-2 +BS-60	75.67	132.33	57.90	4.000	44.07	12.27	84.33	4.133	6.293	14.97	1.260	7.400	42.02
G-2+BS-3	75.67	136.33	51.60	4.067	38.47	11.63	65.27	3.633	6.267	15.87	1.253	9.540	39.52
G-2+PM-78	64.33	119.33	58.74	3.933	47.81	10.00	82.20	3.300	5.860	16.03	1.157	6.927	35.41
G-2+BS-16	82.00	138.33	83.90	4.133	51.47	12.20	88.53	3.467	8.333	19.83	1.667	9.543	41.86
G-2+ Ramsom	68.33	124.00	57.30	4.033	50.87	10.70	84.93	3.567	6.390	17.17	1.243	8.010	36.62
BS-60+BS-3	71.33	131.00	44.90	4.700	33.67	10.90	65.67	3.967	8.167	15.50	1.633	13.31	52.64
BS-60+PM-78	66.33	125.67	43.37	3.633	38.69	10.37	54.53	3.800	7.267	17.73	1.457	13.14	41.13
BS-60+BS-16	75.33	136.67	55.73	3.167	37.62	11.97	64.62	3.567	7.633	17.10	1.523	11.12	44.60
BS-60+ Ramsom	67.00	122.67	39.39	2.267	25.24	10.57	36.53	3.440	3.967	11.16	0.793	11.54	37.40
BS-3+PM-78	59.33	124.33	40.10	2.533	26.14	10.57	48.33	3.493	6.100	13.60	1.220	13.96	45.08
BS-3+BS-16	81.00	142.33	59.22	4.267	44.10	10.97	70.63	3.500	8.833	20.40	1.767	12.19	43.28
BS-3+ Ramsom	65.67	123.67	35.67	2.267	27.33	9.473	35.83	3.400	4.200	12.70	0.840	11.97	33.41
PM-78+BS-16	68.67	135.33	57.00	3.067	34.13	9.000	52.10	3.200	6.633	15.90	1.327	12.51	41.85
PM-78+ Ramsom	56.67	111.67	38.08	2.467	29.53	8.707	33.53	3.287	4.000	11.71	0.801	12.22	35.22
BS-16+ Ramsom	72.67	130.00	66.12	3.433	39.00	9.400	59.13	3.090	6.900	18.90	1.380	12.11	37.13
SE(±)	0.544	0.6315	2.149	0.286	4.012	0.513	7.326	0.170	0.677	1.455	0.135	0.766	3.053

Table 5. Analysis of variance for different characters in a 7×7 mechanical diallel population of soybean in experimental Set I

ITEM	Df	Days to 90% flowering	Days to Maturity	Plant Height (cm)	Branch/ plant	Pods/ Plant	Seeds/ 5-Pod	Seeds/ Plant	Pod Length (cm)	Yield/ Plant (g)	Biological yield/Plant (g)	Yield/ Plot (kg)	100-Seed weight (g)	Harvest Index (%)
Replication	2	0.321	0.905	7.717	0.108	1.181	3.015	21.275	0.137	0.134	0.041	0.007	1.255	20.818
Treatment	27	184.64**	221.36**	585.23**	3.77**	575.99**	11.11**	2702.36**	0.370**	18.84**	65.86**	0.759**	9.160**	192.49**
Error	54	0.889	0.707	18.195	0.303	42.181	1.005	180.46	0.055	1.165	7.186	0.049	0.500	19.252

**P<0.01

Table 6. Analysis of variance for different characters in a 7×7 mechanical diallel population of soybean in experimental Set II

ITEM	Df	Days to 90% flowering	Days to Maturity	Plant Height (cm)	Branches/ plant	Pods/ Plant	Seeds/ 5-Pods	Seeds/ Plant	Pod Length (cm)	Yield/ Plant (g)	Biological yield/Plant (g)	Yield/ Plot (kg)	100-Seed weight (g)	Harvest Index (%)
Replication	2	0.333	2.369	30.185	0.596	354.449	1.429	1504.319	0.072	12.021	39.866	0.474	4.118	79.723
Treatment	27	181.96**	241.40**	614.11**	2.419**	408.08**	7.31**	1603.47**	0.23**	15.55**	43.78**	0.62**	15.45**	229.21**
Error	54	0.889	1.196	13.850	0.246	48.291	0.789	160.989	0.087	1.376	6.348	0.055	1.759	27.968

** P<0.01

In respect of branches/plant, the genotype BS-16 had maximum no. of branches/plant in Set I; but in Set II BS-60 had maximum branches. The biblend BS-60+BS-16 in Set I and BS-3+BS-16 in Set II had maximum no. of branches/plant.

Pods per plant is one of the main factors influencing yield. The genotype G-2 had maximum pods in both Set I and Set II. The biblend BS-3+ BS-16 in Set I and G-2+BS-16 showed the best performance for this trait.

Seeds per pod is one of the main decisive indicators for yield. The genotype G-2 showed best performance for this trait. Among the biblends, the mixture BS-3+BS-16 in Set I and G-2+BS-60 in Set II had the best performance for seeds per pod.

The genotype G-2 had the maximum no. of seeds/plant for the both sets. Among the biblends, the mixture BS-3+BS-16 in Set I and G-2+ BS-16 in Set II gave the best performance for number of seeds per plant.

In respect of pod length, the genotype BS-3 in Set I and BS-60 in Set II had the longest pod. The biblend BS-60+BS-3 in Set I and G-2+BS-60 in Set II showed maximum pod length.

In respect of yield/plant the genotype G-2 in Set I and BS-16 in Set II performed best for this trait. The mixture BS-3+BS-16 showed the best performance in both sets.

In case of biological yield/plant, the genotype G-2 in Set I and BS-16 in Set II performed best. Among the biblends the mixture BS-3+BS-16 in Set I and Bs-60+Ramsom in Set II gave maximum biological yield/plant.

In respect of yield/plot, the genotype G-2 in Set I and BS-16 in Set II gave maximum yield/plot. The mixture BS-3+BS-16 had the best performance for this trait, in both sets.

The uniblend Ramsom in Set I and BS-16 in Set II showed maximum 100-seed weight. Whilst the biblend BS-60+BS-3 in Set I and BS-3+PM-78 in Set II gave maximum 100-seed weight, reflecting bold seed size.

In respect of harvest index (%), the genotype BS-3 in Set I and BS-60 in Set II had the most desired performance for this trait. Among the biblends, BS-60+BS-3 in Set I and BS-3+PM-78 in Set II had the highest harvest index.

On overall rating, the study reveals that the genotype G-2 showed best performance for most of the vitally important characters such as pods per plant, seeds/plant, yield/plant, biological yield/plant and yield/plot.

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 7×7 uniblends and biblends population for different character in two sets are presented in Table 7 and 8. The estimates of general mixing ability (GMA) effects of the seven genotypes and specific mixing ability (SMA) effects of their biblend in both sets are presented in Table 9 and 10.

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

1. Good for highest value of GMA effect
2. Poor for lowest value of GMA effects and
3. 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 SCA variance for the concerned traits.

4.2.1 Days to 90% flowering

Days to 90% flowering exhibited highly significant MS for general and specific mixing abilities in both sets (Table 7 & 8). The ratio of GMA:SMA effects (>1) indicated however the predominance of GMA variance components in influencing the trait.

The negative GMA effects for days to 90% flowering are an indicator for desirable genotype for early flowering. Highest significant negative value of PM-78 and Ramsom thus indicated them as the desirable genotypes for early flowering among the uniblends under two experimental sets. While the uniblend G-2 was the poor general mixture for this trait in both sets (Table 9 & 10).

Table 7. Analysis of variance for mixing ability for different characters in a 7 × 7 mechanical diallel population of soybean in experimental Set I.

ITEM	Df	Days to 90% flowering	Days to Maturity	Plant Height (cm)	Branches/ plant	Pods/ Plant	Seeds/ 5-Pods	Seeds/ Plant	Pod Length (cm)	Yield/ Plant (gm)	Biological yield/plant (gm)	Yield/ Plot (kg)	100-Seed weight (gm)	Harvest Index (%)
GMA	6	262.156**	309.95**	770.58**	4.534**	463.05**	11.72**	2464.11**	0.337**	15.24**	50.31**	0.621**	9.87**	174.40**
SMA	21	4.233**	6.314**	34.85**	0.321**	115.21**	1.372**	454.13**	0.062**	3.677**	13.85**	0.148**	1.115**	32.67**
Error	54	0.263	0.236	6.065	0.101	14.06	0.335	60.154	0.018	0.388	2.395	0.016	0.167	6.417
GMA:SMA		61.93: 1	49.09: 1	22.11 : 1	14.12:1	4.01:1	8.54:1	5.42:1	5.43:1	4.11:1	3.63:1	4.19: 1	8.85: 1	5.34: 1

** P<0.01 ; * P,0.05

Table 8. Analysis of variance for mixing ability for different characters in a 7 × 7 mechanical diallel population of soybean in experimental Set II

ITEM	Df	Days to 90% flowering	Days to Maturity	Plant Height (cm)	Branches/ plant	Pods/ Plant	Seeds/ 5-Pods	Seeds/ Plant	Pod Length (cm)	Yield/ Plant (gm)	Biological yield/ plant (gm)	Yield/ Plot (kg)	100-Seed weight (gm)	Harvest Index (%)
GMA	6	261.25**	596.69**	874.74**	2.35**	507.04**	9.235**	1966.99**	0.26**	19.78**	45.18**	0.789**	19.14**	272.06**
SMA	21	3.340**	37.77**	11.99**	0.366**	30.02**	0.499**	125.21**	0.025	1.011*	4.576**	0.040*	1.148**	20.50**
Error	54	0.296	0.399	4.617	0.082	16.20	0.263	53.66	0.029	0.459	2.116	0.018	0.586	9.323
GMA:SMA		78.2: 1	15.8: 1	72.9:1	6.4:1	16.9:1	18.5: 1	15.7: 1	10.4:1	19.56:1	9.87:1	19.7:1	16.67: 1	13.27: 1

** P<0.01; * P<0.05

Results from the study revealed that the estimates of SMA effects in Set I ranged from 2.545 (BS-60+PM-78) to –3.806 (BS-60+BS-16) and, in Set II from 2.139 (BS-60+PM-78) to –4.046(BS-60+BS-16). In both environments, BS-60+BS-16 was good specific mixture and BS-60+PM-78 was under the category of poor specific mixture. The rest of mixtures were average (Table 11 & 12).

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

4.2.2 Days to maturity

Anova for mixing ability (Table 7 & 8) 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 –8.28 (Ramsom) to 8.089 (BS-16) in Set I and from –14.549 (PM-78) to 9.517 (BS-16) in Set II (Table 9 & 10). Results from both sets clearly showed genotypes PM-78 and Ramsom were by for the two most desirable genotypes for early maturity, they were thus best general mixer for this trait. On the other hand, the genotype BS-16 was poor general mixer for early maturity.

For SMA effects, the estimates ranged from –4.296 (BS-60 + BS-16) to 5.22 (PM-78 + BS-16) in Set I and –3.703 (BS-60 + BS-16) to 9.364 (BS-60 + PM-78) in Set II (Table 11 & 12). The biblend BS-60+BS-16 showed highest

Table 9. Estimates of general mixing ability effects for different characters in a 7 × 7 mechanical diallel population of soybean in experimental Set I

Genotypes	Days to 90% flowering	Days to Maturity	Plant Height (cm)	Branches/ plant	Pods/ Plant	Seeds/ 5-Pods	Seeds/ Plant	Pod Length (cm)	Yield/ Plant (gm)	Biological yield/plant (gm)	Yield/ Plot (kg)	100-Seed weight (gm)	Harvest Index (%)
PB-1	-0.831**	2.868**	-9.47**	-0.53**	-6.62**	-1.173**	-11.65**	-0.035	-1.19**	-1.54**	-0.24**	0.15	-6.205**
G-2	3.725**	1.386**	11.62**	0.239*	9.24**	1.408**	24.64**	-0.022	0.80**	1.43**	0.158**	-1.94**	2.345**
BS-60	2.502**	1.349**	-5.01**	0.009	3.75**	1.125**	13.37**	0.15**	1.09**	1.36**	0.217**	-0.47**	4.948**
BS-3	1.873**	2.089**	-4.64**	0.153	-2.192	0.619**	-3.07	0.33**	0.43*	-0.06	0.083*	1.51**	4.507**
PM-78	-8.127**	-7.502**	-3.28**	-0.78**	-8.52**	-1.378**	-22.22**	-0.28**	-1.82**	-3.24**	-0.37**	0.46**	-4.585**
BS-16	6.910**	8.089**	14.71**	1.36**	8.44**	0.301	9.88**	-0.05	1.59**	3.73**	0.328**	-0.02	1.218
Ramsom	-6.053**	-8.280**	-3.93**	-0.46**	-4.09**	-0.903**	-10.95**	-0.09*	-0.9**	-1.68**	-0.17**	0.31**	-2.227**
SE (gi)	0.168	0.149	0.782	0.098	1.158	0.176	2.394	0.042	0.193	0.478	0.039	0.125	0.782

** P<0.01; * P<0.05

Table 10. Estimates of general mixing ability effects for different characters in a 7 × 7 mechanical diallel population of soybean in experimental Set II

Genotypes	Days to 90% flowering	Days to Maturity	Plant Height (cm)	Branches/ plant	Pods/ Plant	Seeds/ 5-Pods	Seeds/ Plant	Pod Length (cm)	Yield/ Plant (g)	Biological yield /Plant (g)	Yield/Plot (kg)	100- Seed Weight (g)	Harvest Index (%)
PB-1	-1.291**	4.629**	-9.35**	-0.713**	-9.46**	-1.08**	-17.55**	-0.11*	-1.79**	-2.69**	-0.37**	0.196	-7.149**
G-2	3.894**	1.258	11.97**	0.461**	11.18**	1.10**	21.61**	0.07	0.206	1.183*	0.04	-3.107**	-0.485
BS-60	2.487**	2.517	-3.29**	0.464**	0.654	1.013**	6.744**	0.31**	0.97**	0.146	0.19**	-0.047	7.087**
BS-3	1.487**	3.814	-5.54**	0.176*	-3.87**	0.722**	0.474	0.107*	0.408	-1.058	0.08*	0.946**	4.982**
PM-78	-7.995**	-14.55**	-5.08**	-0.346**	-2.89*	-0.96**	-11.25**	-0.103*	-0.77**	-0.651	-0.15**	1.061**	-2.349*
BS-16	7.19**	9.517**	16.17**	0.469**	8.91**	0.307	13.48**	-0.089	2.46**	4.291**	0.49**	1.022**	3.821**
Ramsom	-5.772**	-7.186**	-4.88**	-0.51**	-4.52**	-1.10**	-13.51**	-0.19**	-1.48**	-1.219*	-0.29**	-0.071	-5.905**
SE(gi)	0.168	1.973	0.669	0.087	1.238	0.158	2.261	0.052	0.209	0.568	0.042	0.237	0.942

*P<0.05; ** P<0.01

significant negative SMA effect in both Set I and Set II. So this was the best specific mixer for early maturity. The biblends PM-78 +BS-16 in Set and BS-60+PM-78 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 & Singh (1999) in lentil for days to maturity.

4.2.3 Plant height

The mixing ability anova shows that both general mixing ability (GMA) and specific mixing ability (SMA) variances were highly significant for plant height in both the experimental sets (Table 7 & 8). 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, however, 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 BS-16 had the maximum positive GMA effect in both sets, indicating its best mixing ability. The genotype G-2 also appeared to be a good general mixer. On the other hand the genotype PB-1 had the maximum negative GMA effect, it was thus the worst general mixer. The rest of genotypes were average general mixer (Table 9 & 10).

For SMA effect five biblends in Set I and two biblends in Set II out of twenty-one, showed significant positive values (Table 11 & 12). Among them BS-3+

Table 11. Estimates of specific mixing ability effects in 21 biblends of a 7 × 7 mechanical diallel population of soybean in experimental Set I

Genotypic mixture	Days to 90% flowering	Days to Maturity	Plant Height (cm)	Branches/ plant	Pods/ Plant	Seeds/ 5-Pods	Seeds/ Plant	Pod Length (cm)	Yield/ Plant (g)	Biological yield/ Plant (g)	Yield/ Plot (kg)	100-Seed Wt. (g)	Harvest Index (%)
PB-1+G-2	-0.287	-3.44**	2.629	0.762**	13.91**	1.028*	35.58**	0.599**	3.27**	5.417**	0.655**	0.071	8.787**
PB-1+BS-60	-0.398	1.259**	1.552	0.425	12.67**	1.61**	30.28**	0.335**	1.67**	2.716	0.336**	0.838*	5.784*
PB-1+BS-3	0.898	-0.148	-1.927	0.411	-6.178	0.017	-13.65**	0.177	-0.585	-1.561	-0.109	1.027**	2.659
PB-1+PM-78	-0.102	1.111*	-2.062	-0.423	-3.824	-0.518	-7.791	-0.112	-0.536	-1.241	-0.096	0.729*	-0.816
PB-1+BS-16	-0.139	-1.148**	-4.627*	0.307	2.273	0.836	7.803	-0.041	0.812	0.804	0.152	-0.960**	6.291**
PB-1+ Ramsom	0.824	0.222	7.473**	-0.141	3.375	-0.261	2.038	-0.116	-0.181	-0.709	-0.041	-1.273**	4.052
G-2 +BS-60	-1.287**	1.074*	-7.420**	-0.775**	-20.64**	-0.804	-32.28**	-0.019	-1.94**	-3.83**	-0.386**	0.549	-2.796
G-2+BS-3	1.343**	4.333**	-8.715**	-0.386	-3.361	-1.46**	-8.844	0.030	-1.38*	-3.299*	-0.275*	0.767*	-0.285
G-2+PM-78	-1.657**	-3.740**	5.416*	-0.057	-3.933	0.834	-10.421	0.008	-0.835	-1.982	-0.155	-1.29**	1.047
G-2+BS-16	1.306**	-1.667**	5.151*	-0.227	-2.757	-1.05**	-8.794	0.012	-1.35*	-0.890	-0.279*	-0.063	-6.202**
G-2+ Ramsom	-1.065*	2.704**	7.388**	-0.242	4.112	1.225*	10.141	-0.003	0.354	0.420	0.061	-1.35**	1.842
BS-60+BS-3	-1.435**	-2.296**	-0.142	-0.023	-12.74**	-0.381	-24.97**	0.159	-1.91**	-4.73**	-0.38**	1.814**	1.639
BS-60+PM-78	2.545**	2.963**	0.346	0.073	8.256*	1.036*	13.019	0.27*	1.80**	2.666	0.369**	-0.370	6.064**
BS-60+BS-16	-3.806**	-4.296**	-5.392*	0.069	0.599	-0.596	-4.819	-0.059	-0.516	-0.092	-0.112	0.071	-3.872
BS-60+ Ramsom	0.491	-0.926*	2.078	0.321	8.234*	0.974	21.78**	-0.040	1.190*	2.452	0.228*	-1.15**	1.874
BS-3+PM-78	-5.806**	-0.778	-1.423	-0.271	-0.233	-1.078*	0.966	-0.35**	-0.559	0.739	-0.103	-0.489	-5.775*
BS-3+BS-16	2.157**	-0.037	14.976**	0.992**	26.86**	1.58**	48.75**	-0.244*	5.12**	11.17**	1.015**	-0.674	-0.598
BS-3+ Ramsom	1.12*	-1.667**	-0.488	0.877**	5.378	1.75**	15.818*	0.168	1.66**	2.575	0.322**	-1.03**	4.647*
PM-78+BS-16	-0.509	5.222**	-0.623	0.221	1.438	1.141*	0.890	0.167	-0.396	-0.219	-0.080	-0.499	-0.905
PM-78+ Ramsom	0.454	-0.407	2.623	-0.849**	-8.027*	-1.79**	-13.488	-0.181	-1.46**	-2.475	-0.291*	0.211	-6.744**
BS-16+ Ramsom	-1.25*	1.421**	-8.004**	0.336	-2.374	-0.168	-7.831	0.089	0.493	-0.917	0.178	0.636	6.903**
SE(S_{ij})	0.489	0.436	2.274	0.285	3.369	0.511	6.961	0.121	0.561	1.389	0.115	0.363	2.274

* $P<0.05$; ** $P<0.01$

Table 12. Estimates of specific mixing ability effects in 21 biblends of a 7 × 7 mechanical diallel population of soybean in experimental Set II

Genotypic mixture	Days to 90% flowering	Days to Maturity	Plant Height (cm)	Branches/ plant	Pods/ Plant	Seeds/ 5-Pods	Seeds/ Plant	Pod Length (cm)	Yield/ Plant (g)	Biological yield/Plant (g)	Yield/ Plot (kg)	100-Seed weight (g)	Harvest Index (%)
PB-1+G-2	-0.972*	-1.89**	0.334	-0.025	-3.454	-0.688	-1.847	-0.032	-0.479	-2.298	-0.093	-1.582*	3.875
PB-1+BS-60	0.769	0.853	3.098	-0.095	3.093	1.132*	9.646	0.30*	1.101	0.905	0.221	0.018	7.216**
PB-1+BS-3	2.11**	-1.11	0.765	-0.77**	-5.41	-0.177	-12.48	0.098	-0.785	0.676	-0.155	1.346	-4.419
PB-1+PM-78	1.25**	6.919**	3.237	-0.251	-0.361	0.633	0.094	0.059	0.126	-0.488	0.325**	0.464	2.569
PB-1+BS-16	-0.269	-1.81**	-2.178	1.134**	11.28**	1.238**	23.90**	-0.039	2.103**	4.27**	0.419**	1.353*	6.93*
PB-1+ Ramsom	-1.31**	-1.11	0.736	0.179	1.279	-0.321	1.603	-0.099	0.165	1.178	0.034	-0.888	-1.83
G-2 +BS-60	-0.417	0.223	-1.063	-0.202	-3.868	-0.213	-0.877	0.29	-0.877	-1.446	-0.159	-0.533	-2.425
G-2+BS-3	0.583	2.927**	-5.102**	0.153	-4.946	-0.556	-13.67*	-0.01	-0.279	0.665	-0.055	0.535	-2.819
G-2+PM-78	-1.27**	4.289**	1.57	0.54*	3.42	-0.503	15.18*	-0.133	0.489	0.421	0.085	-2.193**	0.398
G-2+BS-16	1.21**	-0.77	5.488**	-0.073	-4.726	0.426	-3.416	0.019	-0.261	-0.717	-0.051	0.462	0.678
G-2+ Ramsom	0.509	1.59**	-0.061	0.805**	8.098*	0.333	19.97**	0.215	1.568*	2.126	0.313**	0.021	5.159
BS-60+BS-3	-2.34**	-3.66**	3.455	0.783**	0.778	-1.20**	1.586	0.088	0.854	1.336	0.172	1.241	2.728
BS-60+PM-78	2.14**	9.36**	1.454	0.272	4.821	-0.049	2.174	0.133	1.129	3.162	0.232	0.933	-1.457
BS-60+BS-16	-4.05**	-3.70**	-7.42**	-1.04**	-8.048*	0.279	-12.47	-0.115	-1.73**	-2.413	-0.347**	-1.021	-4.151
BS-60+ Ramsom	0.583	-0.99	-1.378	-0.97**	-7.002	0.287	-13.56*	-0.146	-1.455*	-2.847	-0.289*	0.494	-1.632
BS-3+PM-78	-3.86**	6.73**	0.448	-0.57**	-3.199	0.442	2.244	0.024	0.526	0.233	0.106	0.787	4.598
BS-3+BS-16	2.62**	0.334	-1.681	0.345	2.958	0.429	-0.186	0.016	0.037	-3.759*	0.007	-0.947	-3.369
BS-3+ Ramsom	0.25	-1.295*	-4.179*	-0.68**	-0.386	-0.522	-8.00	0.012	-0.657	-0.096	-0.132	-0.068	-3.513
PM-78+BS-16	-0.231	8.697**	-4.365*	0.001	-7.989*	-0.71	-6.999	-0.073	-0.989	-2.816	-0.196	-0.736	2.536
PM-78+Ramsom	0.731	5.068**	-2.231	0.046	0.827	0.397	1.42	0.109	0.317	-1.496	0.064	0.06	5.628*
BS-16+ Ramsom	1.54**	-0.666	4.573*	0.198	-1.499	-0.174	2.297	0.101	-0.006	0.752	-0.001	-0.011	1.371
SE (Sij)	0.416	0.5739	1.947	0.253	3.601	0.46	6.575	0.152	0.609	1.652	0.121	0.688	2.74

*P<0.05; **P<0.01

BS-16 showed maximum significant positive SMA effect in Set I and G-2+ BS-16 showed maximum significant positive SMA effect in Set II, indicating their best specific mixture ability in respective experimental set. The biblend G-2 +BS-3 in Set I and the biblend BS-60 + BS-16 in Set II had the maximum negative SMA effect indicating their worst specific mixture ability in respective set.

Shukla and Singh (1999) reported predominant role of GMA variance component for plant height in lentil.

4.2.4 Branches/plant

The analysis of variance for mixture ability (Table 7 & 8) 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 G-2 and BS-16 in Set I and G-2, BS-60, BS-3 and BS-16 in Set II showed positive GMA effect. The genotype BS-16 showed maximum positive GMA effect, indicating it to be the best general mixer in both the sets. The genotype G-2 was also a good general mixer for two sets. The genotype Ramsom in Set II and PB-1 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 –0.849 (PM-78+Ramsom) to 0.992 (BS-3+BS-16) in Set I and –0.974 (BS-60+Ramsom) to 1.134 (PB-1+Ramsom) in Set II. The SMA effects thus showed differential results in Set

I and Set II. The biblend BS-3+BS-16 in Set I and G-2+Ramsom in Set II were the best specific mixture for respective environment. However the biblend PM-78+Ramsom in Set I and BS-3+BS-16 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.

4.2.5 Pods/plant

The analysis of variance for mixing ability (Table 7 & 8) shows both GMA and SMA components were important for regulation and variation of the character. The magnitude of GMA: SMA ratio suggested the predominant role of GMA part of the variation.

The estimates of GMA effects (Table 9 & 10) show that the GMA effects of nearly all the uniblend genotypes were significant in the two experimental sets except the GMA effect of BS-3 in Set I and BS-60 in Set II. The estimate also indicated that the uniblend G-2 had the maximum positive GMA effect in both the sets, suggesting it to be the best general mixer in both sets. While the uniblend PM-78 in Set I and PB-1 in Set II showed the maximum negative GMA, they therefore could be termed as poor general mixers.

Among the biblends mixers the BS-3+BS-16 followed by PB-1+G-2 in Set I PB-1+BS-16 followed by G-2+Ramsom in Set II showed maximum positive SMA effects, indicating that they were the best specific mixers. The estimates of SMA effects showed differential results between the sets, which might be due to the presence of genotype-cultural set interaction. The biblend G-2+BS-60 in Set I and BS-60+BS-16 in Set II were the poor specific mixers. The rest of biblends were average specific mixers.

Shukla and Singh (1999) reported both GMA and SMA components to be important for pods/plant in lentil.

4.2.6 Seeds/5-pods

For seeds/5-pods mean square due to GMA & SMA were significant, indicating that both these components were responsible in controlling variation of this trait (Table 7 & 8). 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 G-2 followed by BS-60 in both sets, suggesting their best general mixing abilities. While the uniblend PB-1 in Set I and uniblend Ramsom in Set II showed the maximum negative GMA effect in respective set, indicating their poor general mixing abilities. The rest of uniblends were average general mixers (Table 9 & 10).

The SMA effects (Table 11 & 12) ranged from –1.789 (PM-78+Ramson) to 1.747 (BS-3+Ramson) in Set I and –1.202 (BS-60+BS-3) to 1.238 (PB-1+BS-16) in Set II. Out of twenty-one biblends, seven biblends in Set I and two biblends in Set II had significant positive SMA effects. Among them the biblends BS-3+Ramsom in Set I and PB-1+BS-16 in Set II had maximum positive significant SMA effect, indicating their best specific mixing abilities for this trait. The biblends PM-78+Ramsom in Set I and BS-60+BS-3 in Set II were poor specific mixers for this trait. The rest of biblends were average specific mixers.

Shukla and Singh (1999) reported that only SMA variance component was important in seeds/pod in lentil, which partially supported the present experiment.

4.2.7 Seeds/plant

Both GMA and SMA variances were significant for seeds/plant. The genetic system governing this trait might therefore be influenced by GMA and SMA components with former playing more greater role as suggested by high GMA: SMA ratio.

The results of GMA effects (Table 9 & 10) showed that the GMA effects of all the genotypes except BS-3 were significant in both the sets. The highest effect was observed in uniblend G-2 and the lowest PB-1, in both sets. Thus the uniblend G-2 and PB-1 were the best and worst general mixers for this trait. The rest of uniblends were average general mixers.

Among the biblends PB-1 +G-2, PB-1+BS-60, BS-60+Ramsom, BS-3+BS-16 and BS-3+Ramsom in Set I, and PB-1+BS-16, G-2+PM-78 and G-2+Ramsom in Set II showed positive significant SMA effects. The biblend BS-3+BS-16 in Set I and PB-1+BS-16 in Set II showed highest SMA effect indicating the best specific mixers in respective set. While the biblend G-2+BS-60 in Set I and BS-60+Ramson in Set II had the lowest SMA effect, which suggested that they were poor specific mixers in respective set. The remaining biblends were average specific mixers.

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

4.2.8 Pod length

Anova (Table 7) shows general and specific mixing abilities to be highly significant (P<0.01), 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 (Table 8), 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 part of the variance component in both sets.

The result of GMA effects affirmed that BS-3 and BS-60 in Set I, and BS-60 and BS-3 in Set II, in that order, had good general positive GMA effect in respective set (Table 9 & 10). The uniblend PM-78 in Set I and Ramsom in Set II showed maximum negative GMA effect. Thus these uniblends could be termed as poor general mixer in respective set. The GMA effects of the rest were average.

SMA effect (Table 11 & 12) showed that the biblend PB-1+G-2 in Set I and PB-1+BS-60 in Set II had maximum significant positive estimate for this trait, indicating them to be best specific mixers in respective environment. The biblend BS-3+PM-78 and BS-60 + Ramsom in Set II had maximum negative SMA effects, indicating that they were poor specific mixers. Venkateswarlu & Singh (1982) in peas (*Pisum sativum*) found both GMA and SMA effects to be important for pod length.

4.2.9 Yield/plant

Variances due to GMA and SMA were significant (P<0.01) for yield/plant (Table 7 & 8). The analysis clearly demonstrated that both GMA and SMA components played role in the expression of the character. However, GMA component seemed more influential as shown by relatively larger GMA mean square.

The GMA effects of all uniblends were significant in Set I and in Set II except that of uniblend BS-3 in Set II. The genotypes BS-16 and BS-60 showed maximum positive GMA effect in both sets, indicating the best general mixing ability of these two genotypes. The uniblend PM-78 in Set I and PB-1 in Set II had minimum significant GMA effect, indicating their poor general mixing ability in respective set.

The highest significant SMA effect was obtained in mixture BS-3+BS-16 in Set I and PB-1+BS-16 in Set II, which represented the Poor×Good general mixing combination. While the mixture G-2 +BS-60 in Set I and BS-60+BS-16 in Set II showed minimum significant SMA effects, indicating their poor mixing ability in respective set (Table 11 & 12).

Shukla and Singh (1999) found both GMA and SMA component to be important for seed yield/plant in lentil.

4.2.10 Biological yield/plant

The analysis of variance for mixing ability (Table 7 & 8) shows that both GMA and SMA mean squares were significant for biological yield/plot in both experimental sets. The anova with relatively higher ratio of GMA: SMA means squares indicates the predominant role of additive component on character expression in both sets.

The estimates of GMA effect were significant for all uniblends except BS-3 in Set I, while in Set II GMA effect of PB-1, G-2, BS-16 and Ramsom were significant. Apparently the difference was due to interaction between two experimental sets. In case of Set I, the maximum GMA effect was displayed by the uniblend BS-16 followed by G-2 and BS-60. Similar result was obtained in Set II. Thus the genotype BS-16 had the best mixing ability. The genotypes G-2 and BS-60 were also good mixer. The GMA effect of genotype PM-78 in Set I and that of genotype PB-1 in Set II showed maximum negative significant effect, which suggested their poor mixing ability in respective set. The rest of genotypes had average mixing ability.

The highest value of SMA (11.17) in Set I was obtained in biblend BS-3+BS-16 which was a mixture of good + poor general mixers (Table 11). In Set II, PB-1+BS-16, a combination of poor and good mixers had the highest value of SMA effect (Table 12). In Set I the biblend PB-1+G-2 was also a good specific mixer for biological yield. The lowest value of SMA effect (-4.734) was found in BS-60+BS-3, at intra-row mix environment (Set I) and in BS-3+BS-16 at inter-row mix environment (Set II).

Shukla and Singh (1999) reported both "GMA conferred additive" and "SMA non-additive" component to be important for total biological yield/plant in lentil.

4.2.11 Yield/plot

Analysis of variances for mixing ability (Table 7 & 8), in both Set I and Set II, indicated the influence of both GMA and SMA variances in the expression of the trait with GMA component playing greater role.

In yield/plot positive GMA and SMA effects are preferred. All the GMA values of the uniblends were significant in both sets. Based on the GMA effect the genotypes BS-16, BS-60, G-2 and BS-3 were desirable for both mixing sets. Among the uniblends, BS-16 showed maximum positive significant GMA effect, indicating it's best general mixing ability. While the uniblend PM-78 in Set I and PB-1 in Set II had maximum negative GMA effect, suggesting their poor general mixing ability for this trait (Table 9 & 10).

Out of twenty-one biblend mixtures, PB-1+G-2 showed maximum positive significant SMA effect, indicating it's best specific mixing ability in Set I. The biblends of PB-1+BS-60, BS-60+PM-78, BS-60+Ramsom, and BS-3+Ramsom were also good specific mixers in Set I. Whilst in Set II PB-1+BS-16 was the best specific mixer. The biblends PB-1+PM-78 and G-2+Ramsom were also good specific mixers. But G-2+BS-60 in Set I and BS-60+BS-16 in Set II made the worst specific mixers (Table 11 & 12).

Shukla and Singh (1999) found GMA and SMA part played important role in yield/plant in lentil.

4.2.12 100-seed weight

Mixing ability anova (Table 7 & 8) shows GMA and SMA variances were both important for 100-seed weight in both experimental mixing sets (Table 7 & 8). 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.

The trend for GMA effect on an average of most of the genotypes was similar in the both sets (Table 9 & 10). The uniblend genotype BS-3 in Set I and PM-

78 in Set II showed maximum positive significant GMA effect, suggesting their best general mixing ability. On the contrary G-2 in Set I and Set II had maximum negative significant GMA effect, indicating it's poor general mixing ability for the trait.

The estimates of SMA effect showed that the biblend of BS-60+BS-3 had the maximum positive significant SMA effect which suggested it's best mixing ability for this trait in Set I. But in Set II PB-1+BS-16 had the maximum positive SMA value. The differential result was probably due to environmental interaction between the sets.

The mixture of G-2+Ramsom and G-2+PM-78 in Set I and Set II, respectively were the poor specific mixers (Table 11 & 12). Shukla and Singh (1999) reported that both GMA and SMA part were important for 100-seed weight in lentil.

4.2.13 Harvest index

The analysis of variance for mixing ability (Table 7 & 8) shows that both GMA and SMA mean square were significant for harvest index in both mixing sets. The relatively higher ratio of GMA: SMA mean square indicates the predominant role of GMA component on the character expression.

The estimates of GMA effect were significant for most of the genotypes in both Set I and Set II except BS-16 and G-2 in Set I and Set II, respectively (Table 9 & 10). The genotype BS-60 had the maximum significant positive GMA value, indicating it's best mixing ability for this trait in both the sets. While PB-1 had the lowest mixing ability.

For SMA effect the highest value was obtained in the mixture PB-1+G-2 and PB-1+BS-60, respectively in Set I and Set II (Table 11 & 12).

While lowest SMA for harvest index was obtained in the mixer PM-78+ Ramsom in Set I and PB-1+BS-3 in Set II.

Shukla and Singh (1999) found that both "GMA conferred additive" and "SMA conferred non-additive" variance were important for harvest index in lentil.

CHAPTER V
SUMMARY

Mixing ability analyses of yield and component characters of soybean (*Glycine max* L.) were carried out in 7×7 mechanical diallel 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 stand of them in both sets. Seven genotypes used in the study are PB-1, G-2, BS – 60, BS-3, PM-78, BS-16 and Ramsom. The characters studied are days to 90% flowering, days to maturity, plant height, branches/plant, pots/plant, seeds/plant, pod length, yield/plant, biological yield/plant, yield/plot, 100-seed weight and harvest index. The results of the investigation are summarized as follows:

5.1 Genotypic mean performance

All the 28 mixtures (7 uniblends and 21 biblends) showed significant differences ($P<0.001$) for all the characters under study. Among the uniblends PM-78 took minimum time for days to 90% flowering and maturity in both sets. Uniblend BS-16 showed best performance for plant height in Set I & II, branches/plant in Set I, yield/plant in Set II, biological yield/plant in Set II, 100-seed weight and yield/plot in Set II, BS-60 had maximum performance for branches/plant, pod length and harvest index in Set II. The genotype G-2 showed best performance for yield/plant, biological yield/plant, yield/plot, in Set I. But in respect of pods per plant, seeds/pods and seeds/plant the genotype G-2 had best performance for both sets. The genotype BS-3 showed maximum performance for pod length and harvest index in Set I. The uniblend Ramsom had bold seed in terms of 100-seed weight in Set I.

Among the biblends, the mixture of two genotypes PM-78 + Ramsom showed earliest flowering behaviour and the mixture BS-3 + BS-16 showed earliest maturity for both the sets.

The biblend G-2 + BS-16 had maximum performance for plant height in set I & II, pods per plant in Set I and seeds/plant in Set II. The mixture BS-60 + BS-16 showed highest performance in respect of branches/plant in Set I. The biblend BS-3+BS-16 had best performance for branches/plant in Set II; while for pods/plant, seeds/pod, seeds/plant, and biological yield/plant in Set I; and for yield/plant, yield/plot in both sets. The mixture G-2 + BS-60 performed best for seeds/pod and pod length in Set II. The biblend BS-60+BS-3 had best performance in respect of pod length, 100-seed weight, and harvest index in Set I and, biological yield/plant in Set II. Maximum biological yield/plant was obtained in BS-60 + Ramsom in Set II.

5.2 Mixing ability studies (Mechanical mixing)

Mixing ability analysis revealed significant GMA and SMA variances ($P<0.05$-0.01) for most of the characters studied, suggesting the role of both variances in the control of these characters. In all the characters GMA: SMA ratio was greater than unity, indicting the predominance of GMA variances in the character expression.

Higher negative GMA of PM-78 and Ramsom for days to 90% flowering and days to maturity, respectively indicated them to be the desirable genotypes for these two traits. For experimental Set I, the highest GMA effects for plant height, branches/plant, yield/plant, biological yield plant^{-1} and yield plot^{-1} were performed by BS-16, which indicated its best general mixing ability for these traits in Set I. The genotype G-2 had highest GMA variances for pods/plant, seeds/5-pods, and seeds per plant in Set I; thus it was desirable for these traits in Set I. The highest GMA effect was obtained in BS-60 for pod length and 100-seed weight in Set I, suggesting its best general mixing ability in that mixing set but for harvest index, the highest GMA effect in Set I was recorded in uniblend BS-60.

In Set II, the highest GMA for plant height, branches/plant, yield/plant, biological yield/plant and yield/plot was found in BS-16, suggesting its best general mixing ability for the trait. For pods/plant, seeds/5-pods and seeds/plant the highest GMA effects were recorded in G-2 in Set II. The uniblend BS-60 had highest GMA effect for pod length and harvest index in Set II. The highest GMA effect for 100-seed weight was recorded in uniblend PM-78 in Set II, reflecting its best general mixing ability for this trait in that set.

In experimental Set I, highest negative SMA effects were observed by biblend BS-3+PM-78 and BS-60 + BS-16 for days to 90% flowering and days to maturity, indicating their best specific mixing ability in respective experimental set. The biblend BS-3+BS-16 had highest SMA effect for plant height, branches/plant, pods/plant, seeds/plant, yield/plant, biological yield/plant and yield/plot, suggesting their best specific mixing abilities for Set I. For seeds/5-pods, the biblend BS-3+ Ramsom had highest significant SMA effect. The biblends PB-1 + G-2 and BS-60+BS-3 had highest SMA effects for pod length, harvest index and, 100-seed weight respectively, indicating their best specific mixing ability for experimental Set I.

In experimental Set II, the minimum negative SMA effects were recorded in biblend BS-60 + BS-16 for days to 90% flowering and days to maturity, indicating their mixing ability for earliness in Set II. The biblend PB-I+PM-78 had highest SMA effect for branches/plant, pods/plant, seeds/5-pods, seeds/plant, yield/plant, biological yield/plant, yield/plot, and 100-seed weight, indicating its best specific nixing ability for reparative experimental set. The highest SMA effect for pod length and harvest index were recorded in biblend PB-1+BS-60 and the biblend G-2+BS-16 for branches/plant in experimental Set II, indicating them to be desirable mixtures, for Set II.

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^{-1}, seed plant^{-1}, yield plant^{-1}, harvest index and 100-seed weight need to be considered.

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 soybean, this study can be used in synthesizing mixtures of genotypes provided the commercial product is more or less homogeneous.

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APPENDIX

Appendix 1. Meteorological data as recorded for the experimental period at BAU farm Mymensingh

Month	Year	Air Temperature*(⁰C)			Average* Humidity(%)	Total Rain** fall(mm)	Total Sunshine** (hrs.)
		Maximum	Minimum	Average			
November	2001	29.49	19.55	24.52	84.27	10.7	222.7
December	2001	26.52	13.19	19.85	80.84	00.0	220.2
January	2002	25.43	12.43	19.18	78.00	05.3	213.2
February	2002	27.70	15.39	21.55	72.68	Trace	247.6
March	2002	30.00	19.00	24.50	73.61	34.4	239.3
April	2002	29.90	21.69	25.79	80.90	259.8	213.3

* Monthly average, ** Monthly total
Source: Weather yard, Department of Irrigation & Water Management, BAU, Mymensingh