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SOYBEAN BREEDING STRATEGY FOR PAKISTAN: GENOTYPE x ENVIRONMENT INTERACTION AND STABILITY FOR SOYBEAN YIELD

By

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ABSTRACT

SOYBEAN BREEDING STRATEGY FOR PAKISTAN:

GENOTYPE x ENVIRON MENT INTERACTION AND STABILITY FOR

SOYBEAN YIELD

By

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The experimental material comprising of nine soybean cultivars were planted during two seasons (spring and autumn) at four locations for three years 1992-94. Cultural operations were done when needed. Variances due to genotypes, environments and genotypes x environment interaction were highly significant for days to flowering, days to maturity, plant height, first mature pod height, 100 seed weight, number of pods per plant, oil content and yield. Whereas analysis of variance for number of seeds per pod showed non-significant differences for genotypes, environment and their interaction, 'NARC-III', 'NARC-IV' and 'Swat-84' showed stability, in general, for days to flowering and 'NARC-IV' and 'Swat-84' showed stability in maturity. In plant height, 'NARC-III' and 'NARC-IV' performed better in good environmental conditions. Harper showed stability for pod height, whereas 'NARC-V' was found stable for number of pods per plant while 'Harper', 'Swat-84' and 'Williams-84' showed moderate stability for number of pods per plant. All genotypes showed differential response and stability for 100 seed weight. 'NARC-III' and 'NARC-IV' exhibited stability while 'FS-85' and 'William-82' showed stability for 100-seed weight. 'Harper' and 'NARC-III' had the highest oil content. 'NARC-III', 'NARC-IV' and

'NARC-V' were found stable and high yielding in low rainfall areas like Fatehjang and NARC. During spring, 'NARC-III' proved to be a better stable genotype for Gujranwala while 'NARC-IV' for Multan and 'NARC-V' for NARC are recommended due to their high yield potential. 'NARC-V' showed wider adaptability and hence it was identified as a stable genotype on overall basis. A Plant breeding model has been described which will be very useful for the development of soybean cultivars as well as other commodities for different ecological zones in Pakistan.

DEDICATION

IN THE NAME OF ALLAH
“THE BENEFICENT AND THE MERCIFUL”

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List of Abbreviations

Abbreviation	Word of sentence
AARI	Ayub Agricultural Research Institute
ARI	Agricultural Research Institute
b	Regression coefficient
C	Centighrade
CM	Centimeter
CV	Coefficient of variation
DF	Degree of freedom
et al.	and others
Fath	Fatehjang
FS-85	Fasialabad-85
Guj	Gujranwala
kg/ha	Kilogram per hectare
Max	Maximum
Min	Minimum
mm	Millimeter
Mul	Multan
NARC	National Agricultural Research Centre
NS	Non-significant
ORI	Oilseed Research Institute
%	Percent
R	Coefficient of determination

Sd	Deviation from regression
Std.error	Standard error

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INTRODUCTION

CHAPTER–I

INTRODUCTION

Agriculture is the largest sector of the Pakistan economy and contributes more than 24.5 percent to the Gross Domestic Production (Pakistan Economic Survey, 1998-99). Most of the population directly or indirectly depends on this sector. Agriculture employs about half of the total employed labor force and is the main source of foreign exchange earnings. The performance of agriculture depends largely on the vagaries of nature. Despite the best efforts of the farmers, climatic conditions adversely affect the output of crops.

In fact, the development efforts in the agriculture sector in the past had primarily focused on production and development of cereal crops like wheat and rice and cash crops like cotton. These efforts have provided rich dividends in the form of self-sufficiency and production of exportable surplus. As a result, the land area under cereal and cash crops increased while it decreased under oilseed crops (Table 1A). The worsening situation of a decrease in production of edible oil now demands a major shift with endeavors to develop varieties of different oilseed crops with high yield potential under different environmental conditions.

Pakistan is chronically deficient in the production of edible oil; so much so that 72 percent of the country's requirements are met through imports costing huge amounts in foreign exchange (Table 2A). One disturbing aspect of this crisis is an annual increase of approximately 50,000 tons in the gap between consumption and domestic production (FAO 1999). It is a matter of great concern that efforts made so far to enhance domestic production of edible oil have not had any significant impact. Edible oil is second only to petroleum among commodities being imported into Pakistan and requires a large amount of foreign exchange. During 1998-1999, the total domestic production of edible oil was 532 thousand tons, of which about 72 percent was obtained from cotton, while *Brassica* sp. contributed 14 percent and the remaining production was from other crops like sesame, sunflower, soybean, safflower and maize (Table 3A).

The factors contributing to the increase in consumption of about 50,000 tons per year are as follows:

- Population increases
- Per capita consumption increase
- Increasing urbanization
- Higher family incomes leading to a better standard of living
- Decreased per capita availability of animal fat and its higher cost

Soybean is an excellent crop for edible oil and its seeds contain 18-20% oil, 40-42% protein, 19-25% carbohydrate, 4-5% fiber, 5% ash, and 80-85% unsaturated fatty acid plus vitamin B and no cholesterol. Thus, soybean would provide not only good quality oils but also much needed protein for Pakistan. Animal meat is very expensive and is not available in good quality. Therefore, soybean will not only be a source of edible oil but also provide a source of quality protein, which an ordinary farmer can afford. The total area under soybean production in the world is about 69.4 million ha yielding 152.6 million tons (Soy and oilseed Blue book, 1999), which signifies its importance and popularity as food and a versatile crop. Of this total, the United States contributes 47%, Brazil 20%, Argentina 11%, China 10%, India 3%, Canada 2%, and Paraguay 2%, The European Union contributes 1% and other countries, 4%.

Soybean has a lot of potential and can be successfully grown in Pakistan. The existing cropping system (Table 5A) in the cotton area is cotton-wheat-cotton (Akhtar et al. 1986) while in the rice area, it is rice-wheat-rice-wheat (Byerlee et al., 1984) and in the rain-fed area wheat- sorghum - fallow or wheat – fallow – wheat (Byerlee et al., 1984; Hobbs et al., 1983; Hobbs et al., 1984; Riaz et al., 1983;). The cotton crop yield has been affected by the existing cropping system due to continuous planting of the same crops without following any rotation. In the cotton area, the last picking is done during mid January, and it will not be economical to plant wheat at that time. But most farmers' complete cotton picking occurs during the 1st week of December, with wheat planting done during the 2nd week of December. This is not as profitable as if wheat planting is done between October 15 to November 15, which is the optimum time to get the maximum yield of wheat. But the farmers follow the existing system because there is no other choice except wheat.

Similarly, in rice area, the land is wet and not ready for wheat planting at the proper time so the planting of wheat is delayed, which affects its production. Results of the experiments conducted under different ecological conditions indicate that soybean can be productive and can fit into a cotton, rice and rain-fed cropping system (Table 6A). In rainfed areas, there is ample of rain (Table 7A – 10A), which can be utilized by planting soybean in the fallow area. Soybeans can fit into new cropping systems in the cotton, rice and in the rainfed area because 30%, 30% and 25% remains fallow in these areas respectively due to one reason or the other (Table 11A). As a leguminous crop, soybean will improve the soil fertility (Porter et al. 1997). By planting soybeans in rotation, soil erosion, diseases and insect damage will be minimized. Soybeans will also provide additional income to the farmers.

The commercial cultivation of soybean in Pakistan started in the early 1970. Prior to that time, soybeans were practically unknown in the plains of Punjab and Sindh (Table 12A). However, some local black and chocolate colored varieties of pulses now identified as soybean have been grown from time immemorial in the hills of northern parts of Pakistan i.e., Hazara, Azad Kashmir, Swat, Dir and Kurram Agency. To improve the prevailing varieties and to introduce new ones, some research was started in 1965 in North Western Frontier Province (NWFP). Since the establishment of Oilseeds Coordinated Program at Pakistan Agricultural Research Council (PARC), Islamabad in 1977), extensive research work for the development of early maturing and high yielding varieties is in progress at the National Agricultural Research Center (NARC), Islamabad, The Ayub Agricultural Research Institute (AARI), Faisalabad and the Agricultural Research Institute (ARI) in Tandojam, Tarnab (Peshawar), and Sariab (Quetta).

During the past years, efforts have been made by agricultural scientists to introduce soybean commercially but without much success. Expansion of the area planted in conventional oilseed crops is difficult. Still, new varieties of soybean can be developed to fit in the cropping system in the cotton, rice and rain fed areas. During 1970-71, soybean was planted on an area of 2460 hectares, which declined to 1660 hectares in 1976-77. From 1977-78 onward area increased slowly to 5980 hectares till 1986-87, then it fluctuated again in 1998-1999. The production from 1980-1999 is given in Table 13A where fluctuation can be seen for each year.

Recent research revealed that due to lack of adapted high yielding and early maturing soybean varieties, the actual national average is 1/2 of the potential yield. Therefore, to increase the production per unit area, new high yielding and early maturing varieties need to be developed which are suitable for different ecological regions. The national average production (Table 13A) is very low at this stage.

The study of genotype x environment (G x E) interaction has assumed great importance in variety testing programs because the yield performance of a genotype is the result of interaction with the genotype and environment. Environmental factors such as rainfall, temperature and soil fertility play an important role in varietal performance and yield. Therefore, the release of a genotype with consistent performance over a wide range of environments should lead to stability in production. A measure of the relative yield stability of the soybean varieties under a wide range of environmental conditions is essential for determining efficiency in a variety evaluation program.

Genotype x environment interaction studies on soybean has not been done in Pakistan. This initial study will help the development of suitable cultivars for different ecological conditions without disturbing existing cropping systems. Information from the study will determine potential parents that will be used in the genetic improvement program. As a result, scientists should be able to develop suitable cultivars for different environments. The crop area under soybean will be increased which will narrow the production and consumption gap. Substantial work on this aspect has been done in other countries. In most of these studies (Baihaki et al., (soybean) 1976; Baker, (wheat) 1969; Borojevic and William, (wheat) 1982; Brennan and Byth, (wheat) 1979) data from several locations have been used for determining the significance of G x E interaction. However, in the studies of wheat and cluster beans (Luthra et al., 1974; Saini et al., (1977) involving single location experiments, the different environments were created by using different dates of planting, spacing, fertilizer rates, irrigation levels, etc.

Participatory plant breeding (PPB) is defined as a breeding approach that involves a close relationship between farmers and researchers to bring improvement within a plant species. In this dissertation, PPB will refer to the full scope of activities associated with plant genetic improvement which include identification of breeding objectives, generating genetic variability, selecting within variable populations to develop experimental lines, evaluating experimental lines termed "participator variety selection" (PVS), variety release, popularization and seed multiplication activities.

Farmers' participatory plant breeding programs have several important goals, the most important of which is to increase crop production in the farmers' fields. Increasing the income of the farmer through development and adoption of high yielding improved soybean cultivars is important for Pakistan.

This study will develop a new model for plant breeders to set their research agenda. It will address the important issues of today:

- The research-extension linkage
- Participatory Planning and implementation
- Sustainable financing
- Priority setting

This model will outline how priorities can be set for the breeding program. This model will be applicable to all crops in both the developed and developing world.

REVIEW
OF
LITERATURE

CHAPTER-II

REVIEW OF LITERATURE

GENOTYPE-ENVIRONMENT (G x E) INTERACTION AND STABILITY:

Genotype-environment (G x E) interactions have concerned plant breeders for many years. Different procedures have been used to characterize individual varieties for expression in varying environmental conditions. Performance tests are conducted at a number of locations and repeated over several years to find how cultivar response varies to different locations and different climatic conditions. The experiments conducted at a single location and in a single year have a limited utility. Therefore, performance tests over several years and locations are important for the development of cultivars with wide adaptability. Yates and Cochran (1938) proposed a regression model to evaluate the adaptability of a variety over diverse environments. A variety or genotype is considered to be more stable if it has high yielding ability when growing in diverse environments. They used the mean performance of all genotypes grown in an environment as a suitable index of its productivity. The performance of each genotype was plotted against this index for each environment and a simple linear regression was fitted by least squares to evaluate the genotype's response, the mean of the regression slope being one. Jensen and Neal (1952) suggested that genotype x environment interactions would be reduced by using multiline varieties of oats rather than pure line varieties because such multiline varieties would possess greater stability of production, broader adaptation to the environment and greater disease resistance.

Although it is possible through population genetics and biometry to develop breeding programs for crop improvement, the plant breeder must select on the basis of an ever-changing environment. Grafius (1956) studied the components of yield in oats. He stated that yield is not only a ratio but it is also a product. He also concluded that recurrent selection for a ratio, without strong positive correlation between the heritable numbers of the ratio, was likely to be futile. Plaisted and Peterson (1959) computed an analysis of variance for every pair of genotypes to estimate the interaction variance for every combination of two genotypes. The mean of the interaction variance obtained for each genotype was used as an indicator of the contribution of that genotype to the total genotype x environment interaction.

Plant breeders and agronomists are interested in the potential performance of crop varieties over a wide range of ecological conditions. In a study by Finlay and Wilkinson (1963), varieties from particular geographic regions of the world showed a similar type of adaptation, which provides a useful basis for plant introduction. For each variety, a linear regression of yield on the mean yield of all varieties for each site and season was computed to measure variety adaptation. The mean yield of all varieties for each site and season provided a quantitative grading of the environment and from the analysis, Wilkinson concluded that varieties adapted to good or poor seasons and those showing general adaptability can be identified.

It is well known that phenotype reflects non-genetic as well as genetic influences on development and that the effects of genotype and environment are not independent. The phenotypic response to a change in environments is not the same for all genotypes. The main objective of most breeding programs is to select genotypes that will perform well in a broad spectrum of environments or varieties highly adapted for a specific environment. A variety that is superior only in a specific environment has less value than widely adapted cultivars. Comstock and Moll (1963) described the variances which are pertinent to plant breeding problems are those associated with variety x year, variety x location and variety x year x location interactions. Estimates of the magnitudes of these variances relative to each other and relative to the error or plot to plot environmental variance are necessary for the application of existing quantitative genetic theory to plant breeding. They have shown statistically the effect of large G x E interaction in reducing progress from the selection. Allard and Bradshaw (1964) classified the variation of the genotype x environment in two types: predictable and unpredictable. Significant variety x location or variety x year interaction suggested that the appropriate breeding program should allow for the development of a number of varieties, each particularly adapted to one of the special environments. Variety x year interaction is very different from variety x location interaction because year-to-year fluctuation cannot be predicted in advance. They concluded that genetic diversity either as heterozygous or as a mixture of different genotypes often leads to stability under varying environmental conditions.

The occurrence of G x E interaction provided a major challenge in obtaining a fuller understanding of the genetic control of variability. Phenotype is the product of genotype and its environment. Finlay and Wilkinson (1963) developed a statistical technique to compare the yield performance of a set of cereal varieties grown at several locations for several seasons. This involves computing for each variety the regression of individual yield on the mean yield of all varieties for each site and season. For the varieties and sites tested the regressions had a high degree of linearity and were used as measures of the adaptability of the varieties. Similar techniques yielding similar results were reported by Yates and Cochran (1938). Breese (1969) conducted research in grasses to measure the significance of

G x E interactions. His study involved computing for each variety the regression of each individual on the mean yield of all varieties for each site and season. The wide range of genetic material showed marked interaction with contrasting climatic, edaphic and management conditions. The major part of this interaction could be explained by differences between responses as estimated by regression. The results have been used to demonstrate that this method can be a powerful means of predicting relative performance of populations and their hybrids over seasons, years and locations. Green et al., (1972) emphasized the need to develop high yielding cultivars adapted to a specific production environment. The existence of significant interactions between genotypes and the environment supports the need of tailoring genotypes to fit specific environments. Selecting the genotypes possessing the phenotype that permits the best exploitation of the yield potential of a specific production environment is a major objective of plant-breeding programs. To accomplish this objective, the breeder must determine empirically or mechanistically the characteristics and nature of the ideotype so that appropriate germplasm manipulation could be made. Baihaki et al., (1976) conducted a study to determine the relationship of G x E interaction to yield level (high, medium, low) in preliminary yield test material. The regression of stability parameter estimate (b value) on mean yield of the lines was positive and highly significant. In general, the medium yield group of lines was most stable and the low yielding group was the least stable. They concluded that a single environment preliminary yield test could be used without risk of discarding outstanding lines.

Specht and Williams (1978) observed in a temperate, rain-fed climate that soybean lines used in diverse regions were not quite adapted and were not very yield stable in terms of high temperature response. Since temperature in July is very high, breeders must keep in mind the phenotype most likely to elicit the best yield response in such an environment. Critical consideration of these interactions between genotype and the environment permits the breeder to make some mechanistic determinations about the problem comprising the ideotype and supplement the subsequent empirical determination necessary to confirm or deny tentative judgements concerning the nature of the ideotype. The joint expression of non-genetic and genetic factors is reflected by phenotypic performance. The genotype may respond differently to various environmental factors or groups of environmental factors. Baker (1969, for wheat;) and Abou-El-Fittouh et al. (1969, for cotton) found in their studies that the magnitude of the G x E interaction variance has been found to be larger than that for genotypes, making it difficult to recognize small actual differences in yield. Brennan and Byth (1979) studied G x E interaction of widely adapted wheat genotypes. They concluded that greater selection differentials were found in environments when selection was practiced for high mean yield across all environments when the yield of each cultivar in each environment was expressed as a percentage of the environment mean yield.

Since the expression of a character is dependent on the interaction of the genotypes and the environment, the stability of performance in the context of different environments is an important criterion in discriminating varieties. Sharma et al., (1980) conducted research on 28 genotypes of soybeans in kharif (autumn) and spring seasons for 2 years to evaluate level and stability of performance for days to first flowering, days to maturity, and seed yield per plant. They found that the mean differences among the genotypes were highly significant for all the characters. Highly significant genotype x environment interactions were observed for all 3 characters suggesting that the characters were significantly influenced by changes in the environment. The variances due to environment (linear) were significantly different for all the 3 characters, indicating that the response to environments was genetically controlled. The genotype x environment interaction (linear) component of variation for stability was also highly significant for days to first flowering and non-significant for days to maturity and seed yield, which indicated the differential response of the genotypes to different environments. Genotype x environment interaction is important to plant breeders because of the confounding effects it introduces in comparisons among genotypes tested in different environments. Saeed and Francis (1984) conducted research in grain sorghum to determine the relative contribution of several weather variables during various plant growth stages to variation in environment and genotype x environment interaction of grain sorghum genotypes in different maturity groups. They found that variation in weather factors contributed more to G x E interaction for yield of the late maturing genotypes than for the early and medium maturing genotypes.

Evaluation of genotypes for consistency of performance in different environments is important in plant breeding programs. The relative performance of genotypes often changes from one environment to another. The occurrence of a large genotype x environment interaction poses a major problem of relating phenotypic performance to genetic constitution and makes it difficult to decide which genotypes should be selected. It is important to understand the nature of G x E interaction to make testing and ultimately selection of genotypes, more efficient. Saeed et al. (1984) studied the effects of genotype maturity on G x E interaction of sorghum for grain yield and yield components. The genotypes were of three maturity groups; early, medium and late and evaluated in 48 environments in 2 years. They suggested that a reliable evaluation of relative genotype performance could be made if the genotypes under test do not include a wide range of maturities. Testing at more locations should be done rather than testing in more years. For a desired level of precision, the amount of testing required for a set of genotypes with a wide range of maturity and long-growth duration is greater than that required for genotypes with a narrow range of maturity and short-growth duration.

Grain yield is complex and is determined by various qualitative and quantitative characters, which are greatly affected by the environment. Thus, it becomes very important to ascertain the extent of influence of changing environments on grain yield and yield components before recommending a variety for commercial cultivation. Malik and Rajput (1984) conducted research to study genotype x environment interaction on wheat. They concluded that prior to variety release, yield potential and adaptability should be ascertained under different environmental conditions. Pathak and Nema (1984) observed that shorter growth periods between flowering and maturity as well as between pod set and maturity were associated with high yield in an early sown crop while longer growth periods between the beginning and end of flowering and between flowering and maturity were associated with increased yield in a late sown crop.

Genotype-environment interaction is important in evaluating variety adaptation, selecting parents for breeding programs according to the environments, and improving genotypes with improved adaptability. Mariani and Manmana (1986) concluded from the combination of results from different varieties, years and locations that all the regression models applied showed similar efficiency values and analogous stability parameters for each variety. In addition, they also verified by multi-phase regression models whether a specific response to poor, average or rich environments arose for a variety.

The presence of G x E interaction creates difficulties in assessing the performance of different cultivars. This is especially true in food legumes, which are often cultivated under adverse agro-climatic and management conditions. Therefore, it is essential to identify the cultivars which have high yield potential and have stability over a wide range of environments before they are released. Singh and Chaudhry (1985) computed stability analysis for protein and oil contents in different soybean lines in artificial environments. Significant environment and genotype interaction indicated variable response of varieties to a wide range of environments. Similarly, significance of the linear component of environment and G x E interaction indicated the predictability of regression coefficient pertaining to various genotypes on environmental means. They concluded that genotypic differences and G x E interaction were significant for oil content only.

The role of genotype-environment interaction is well known in crop plants. A genotype grown in different environments may have different responses. Similarly, when hybrid populations are grown in different environments, inconsistent phenotypes may appear due to the interaction of genotype and environment. A hybrid population of a self-pollinated crop advanced for several generations under different environments would be very useful in the study of evolution, adaptation, breeding parameters, and genetic variation of the crop. Selection can be carried out in early generation and desired characters can be selected to identify that plants express their potential characteristics when hybrid populations are advanced under favorable conditions [(Iman and Allard, (1965), Goth (1955) and Adair and Jones (1946)]. Chan et al. (1986) studied the frequency distribution of agronomic characters in the F_2 generation of soybean. They concluded that the standard deviation of plant height, nodes on main stem, days to flowering and days to maturity tended to increase from south towards north and suggested that that some differentiation in the F_2 populations under various locations was involved.

Genotype x environment interaction plays an important role on the stability performance of genotypes. If this interaction is high, genotypes become highly adapted to the specific environments. However, if the interaction is low, the genotype performs uniformly over a wide range of environments. Thus, selecting genotypes for performance stability under varying environmental conditions has become an essential part of any breeding program. In order to know the effect of interaction, a number of statistical and biometrical-genetical approaches have been developed by different authors (Finlay and Wilkinson, 1963; Ebberhart and Russell, 1966; Perkins and Jinks, 1968). Konwar and Talukdar (1986) studied soybeans genotypes in different environments to evaluate the stability of performance of genotypes and to identify the stable genotypes with high yielding ability. Sufficient G x E interaction was exhibited by the genotypes for all the characters. However, the characters differed in regards to the contribution of linear and non-linear components of G x E interaction variance. The genotype Bragg exhibited average stability for seed yield per plant followed, by DS73-16 and Kalitur; JS72-375 for number of pods per plant and number of clusters per plant; and PK327 for 100-seed weight exhibited above average stability which can be utilized in a breeding program.

Genotype-environment interaction is important in selecting parents for genetic improvement programs in different environments. Mariani and Manmana (1986) studied the combination of results from several data sets to assess the adaptability of Italian wheat varieties and to verify if stability parameters of varieties planted in some of the environments had the same reliability. Their results revealed that multi-phase regression models applied to the three sets were not significantly different from linear regression; this was used to measure the average sensitivity over all environments for each variety. They also verified by multi-phase regression models whether a specific response to poor, average or rich environments arose for a variety. Stability of performance across environments is considered essential for the release of soybean genotypes with improved oil quality. Recent advances in the development of soybean genotypes with higher oleic acid and lower linolenic acid percentage may be accompanied by changes in genotype x environmental interaction of the selected material. Carver et al., (1986) conducted research on soybean to evaluate stability of unsaturated fatty acid composition in lines derived from the original population and from the third and sixth cycles of recurrent selection for high oleic acid. The regression analysis showed that genotype x environment interaction for each unsaturated fatty acid could be attributed to differences among genotypes in their linear responses to changes in the environmental mean. The stability analysis revealed a higher proportion of selected lines sensitive to environmental variation in oleic and linoleic acid percentages.

Sen and Mukherjee (1986) suggested autumn and late autumn to be relatively more favorable than the rabi and late rabi. They also observed no association between mean yield and stability performance. Molari et al., (1987) reported difficulties in identifying plants in the progenies of a soybean cross and considered it to be due to genotype x environment interaction. They suggested that selection for yield should be based on characters of simple genetic control such as pods per plant. Selection response was estimated for each generation from a comparison of the selected population to the whole population. Early maturity showed a highly significant selection response for seed yield. There was a significant positive response only in the F_5 and this is attributed to a year effect.

Screening of advanced strains for environmental adaptability is very important in India where barley is cultivated over varying soil moisture conditions. Verma et al., (1987) conducted research to evaluate elite lines of barley for yield stability under different environmental conditions. According to pooled analysis there were significant differences among the strains. The significant genotype by environment component indicated real differences in varietal performance over environments. Variance due to pooled deviations was highly significant, indicating that differences in stability were due to the deviation from linear regression and not to the inferences in the slope line.

Odendaal and Deventer (1987) studied genotype x environment interaction that plays an important role for grain yield and protein percentage on soybean cultivars planted at 9 different sites for 3 years. The genetic variance components for yield and protein percentage amounted to 10% and 24% of the total phenotypic variability respectively. The variance components for the cultivators x location and cultivar x year interactions were small for both trials. The second–order interactions were substantial, amounting to 33% and 12% for yield and protein percentage respectively. The error component accounted for 48% and 55% of the respective total phenotypic variances.

Hildebrand et al., (1988) reported that large differences in oil stability analysis were seen in 43 soybean lines. Differences in seed filling and maturing may have affected oil stability. Development of cultivars specifically adapted to later planting dates commonly associated with double-crop production has been suggested as a means to expand double-crop in the area. Raymer and Bernard (1988) conducted research on soybean cultivars to determine if currently used soybean cultivars differ in adaptation to late planting and if any specific traits are related to improved performance under late-planted conditions. Their research was conducted on 16 cultivars for 3 years and 2 dates of planting. Cultivars by planting date interactions were found to be significant for days to maturity, height at maturity, seed quality and seed mottling, but not for yield, days to flowering, height at flowering, lodging and weight per 100 seeds. All cultivars suffered substantial and similar yield reductions when planted late. Phenotypic correlation coefficients of cultivar performance between the two planting dates were positive and highly significant for all plant traits. The relationship of yield with various plant traits varied greatly from year to year and no differences in these relationships were observed between the two planting dates. They concluded that the lack of a strong cultivar by plant date interaction for yield and the lack of any strong associations of specific plant characteristics with yield in late planted environments imply that testing in a conventional early-planted environment will be effective in identifying lines that perform well in either full-season or double-crop environments. To make a rational decision on whether a special selection program is necessary for improving soybean grain yield in an intercrop, information is needed on the effect of intercropping on the expression of genetic variability and genetic parameters, nature and magnitude of association of different traits, and direct and indirect effects of various traits on seed yield. Sharma and Mehta (1988) studied the effect of cropping systems on genetic variability and component analysis in soybean. According to their results, the correlation coefficients between traits were found to differ, both in nature and magnitude, between monoculture and inter-cropping. In monoculture, seed size, harvest index and oil percentage was positively related with seed yield. By contrast, plant height, branches per plant, pods per plant and pod clusters per plant, besides 100-seed weight and harvest index, were correlated with seed yield under inter-cropping. Seed size followed by branches per plant appeared to be the important characters for higher seed yield selection under sole cropping. Yield improvement in inter-cropping was associated with increased harvest index.

Soybean is basically a rainy season crop in India but it can be successfully grown during rabi and summer seasons. The area of soybean in India is increasing very rapidly to bridge the gap between demand and supply of edible oil and protein. Therefore, a study was conducted to evaluate the adaptation of promising soybean cultivars to different seasons. Patil et al., (1989) found significant differences between environments and nonsignificant differences between 25 genotypes of soybean for seed yield. Mean square (MS) for both environment and genotype were observed for days to flowering, days to maturity, plant height and pods per plant when tested against pooled error. Highly significant MS for environment (linear) showed wide differences between environments and had considerable influence on all the characters. Pooled deviations were significant for all the characters indicating significant differences with respect to stability between them. Five genotypes of soybean were found to be comparatively stable for days to flowering whereas for days to maturity. None of the genotypes were significant for date of maturing. Five soybean genotypes had above average stability for plant height. Based on regression coefficient and deviation from regression values, six genotypes showed stability for number of pods per plant.

As in India, soybean is also a rainy season crop in Pakistan but it can also be grown in irrigated areas in Pakistan due to availability of land and irrigation facilities without disturbing the existing cropping system. However, the area under soybean has not been increased in Pakistan due to non-availability of high yielding cultivars suitable in different ecological zones. Patil and Narkhede (1989) conducted research on phenotypic stability of yield, seeds/pod and 100 seed weight in black gram to collect information for launching a dynamic and efficient breeding program. Pooled analysis of variance revealed the presence of genetic variability as well as variable environments for the characters under study. The G x E interaction including environmental linear effects was found to be significant. Highly significant differences were found due to environment for all traits. The linear component of G x E interaction was highly significant for seed yield, seeds/pod and 100-seed weight. They concluded that the prediction for most of the genotypes appeared to be feasible for most characters. Significant pooled deviation for all three characters suggested that the genotypes differed considerably with respect to their stability for these characters. Yadar and Kumar (1983) also reported the linear and non-linear components of G x E interaction for seed boldness in black gram. Clark and Snyder (1989) reported a significant interaction between year and cultivar for seed oil content in different soybean cultivars. Cultivar differences vary by year, and year differences vary by cultivar. The growing conditions were different for each year, but the cultivars did not respond the same to changes in growing conditions. This indicates that cultivars may have individual responses to environmental conditions that influence oil content.

The existence of significant G x E interaction creates difficulty in genetic analysis in several ways, such as by confounding estimates of genetic parameters and statistics, and by complicating selection and testing strategies. Such interactions reflect differences in adaptation, which may be exploited by selection and testing strategies. There is conflict between breeding for broad adaptation (minimizing interaction) and for specific adaptation (emphasizing favorable interactions). However, any objective decision requires a full understanding of the nature of G x E interaction. Kroonenberg and Basford (1989) investigated multiple attributes (seed yield, plant height, and seed protein percentage and oil percentage) in different soybean genotypes at different locations. Standard analysis of variance indicated that many significant differences and interactions exist, but did not give specific information about the response patterns. However, when results of seed quality were compared with emergence in field planting, sometimes inconsistent results have been found. Some inconsistencies among investigations may be due to use of different procedures; however, much of the variation has been attributed to variations in the planting environment. This suggestion implies recognition that different seed lot characteristics may be better related to performance in different field situations, and it has been proposed that seed quality tests should simulate the stresses imposed by different environments (Schoorel, 1957; Woodstock, 1973). Ferris and Baker (1990) reported G x E interaction stability emergence results for five non-flooded soil environments that indicated significant linear and quadratic interaction between seed and environment. From their results, they concluded that the seed quality test, which is best for predicting soybean emergence, could vary with seedbed conditions.

The interaction is usually present whether the varieties are pure lines, single cross or any other material with which the breeder may be working. Qari et al., (1990) conducted a study on ten barley varieties to evaluate for stability over nine locations for two years. Combined analysis of variance revealed significant differences among varieties for yield performance. The G x E interactions were, however, of the non-linear type because variety x environment (linear) was non-significant against pooled deviation. The non-significance of variety x environment (linear) reveals a lack of genetic difference among varieties for their response to varying environments. The variance due to pooled deviation was highly significant, indicating that an important component for difference in stability was due to deviation from linear regression only.

Plant breeders continuously try to find ways to increase the efficiency of selection for seed yield. An important factor in the development of cultivars is yield testing at different locations. Rosielle and Hamblen (1981) suggested that the most desirable approach for plant breeders would be to choose testing sites that are representative of the production areas. Whitehead and Allen (1990) conducted research on soybean to test the genotypes that have superior yield potential in both low and high stress edaphic conditions. Their results indicated that low-stress environments commonly used in soybean breeding programs should provide high probabilities for selecting genotypes that have superior yield potential in both low-and high stress edaphic conditions. Regression coefficients for line mean yields regressed on site mean were generally highest for the superior lines (b> 1.0) but the deviation from regression was similar to the non-superiors lines. The ranges for maturity and plant height were similar for both groups indicating that selection for superior lines would not have led to extremes for either trait.

Harer and Shah (1991) studied stability for seed yield in some soybean varieties during kharif and rabi 1986, 1987 and summer season of 1988. They found that the mean differences among genotypes were highly significant which reveals the presence of genetic variability among the genotypes. Highly significant mean squares due to environments and genotype x environments interaction revealed that the expression of genotypes varied in different environments. The partitioning of G x E interaction into linear and non-linear portions indicated that the mean squares due to linear components played an important role in total G x E interaction. The excess of the linear component revealed that the prediction of performance in different environments would be possible. The stability parameters revealed that all the varieties showed significant linear and non-significant non-linear components.

Mayers et al. (1991) conducted research on adaptation of soybean in three tropical dry season environments to examine genotype and environmental effects on growth and seed yield per plant. They concluded that dry matter (DM) at maturity increased exponentially with crop duration and was greater with later maturing genotypes. Across environments, thermal time provided better description of DM accumulation than did crop duration, indicating direct effects of temperature on growth rates. Among genotypes, the relationship between seed yield and DM production was strongly linear, implying that under the wide spacing of the study, DM production was the main basis of genotype differences in seed yield. Among environmental means, the relationship was weaker and curvilinear; suggesting those environmental effects of vegetative growth were not necessarily reflected in seed yield. They also found that where photothermal regimes delayed flowering and maturity, vegetative growth was excessive, and the harvest index (HI) smaller. HI was also smaller where flowering coincided with cool night temperatures (<c. 14C) and pod set was reduced. HI was negatively correlated with crop production.

In plant improvement programs the understanding of the G x E interaction is very important. Ivory et al., (1991) studied the analysis of the environmental component of genotype x environment interaction in crop adaptation evaluation and observed significant genotype x environment interaction. They identified the environments, which elicit similar patterns of response across genotypes. Grouping environments on the basis of genotype means has been relatively uninformative, because it has largely ignored the G x E interaction. They discussed the group's environments in such a way that the relative, not the actual, genotype performance is similar within environment groups. The use of genotype yield deviations from environment means yield as a measure of the G x E effects were very effective in separating different soybean genotypes responses in different environments. Thus, recommendations of a genotype can be made to the farmer on the basis of their performance to be grown in different regions.

Selection for duration of the seed-filling period (SFP) in segregating soybean populations may be a way to increase yield. However, this should be used with great caution. The positive associations between duration of the seed filling period (SFP) and days to maturity may cause difficulties in improving yield within a given length of growing season because maturity may be delayed as the result of selection for long duration of seed (Reicosky et al., 1982).

The presence of genotype x environment interactions can hinder progress from selection by masking genotype effects (Comstock and Moll, 1963). The magnitude and nature of genotype x environment interactions influence the features of a breeder's selection and testing program. Therefore, the association between plant characteristics and seed yield assumes special importance as the basis for selecting desired soybean strains (Lal and Haque, 1971). Mebrahtu et al., (1991) conducted a field experiment on vegetable soybean to determine the magnitude of genotype x environment interaction of: number of branches per plant, number of nodes per branch, number of nodes per main stem, number of pods per plant, main stem height, main stem internode length, 100-pod weight and green pod yield and also the association among the green pod yield and its components. They concluded from their investigation that genotypes responded differently to year (season), indicating that specific genotypes should be developed for each environment.

The efficiency of crop improvement can be enhanced through the elimination in advance of many of the errors in 'trial-and error' methodology. Plant breeders have developed a range of useful analyses, which enable responses to be described and predictive inference to be drawn from data on the comparative performance of breeding lines across environments. Mostly, these involve the statistical partitioning of the phenotypic performance (P) of individual entries or 'genotypes' in a specific environment into genotype (G), environmental (E) and G x E interaction components. Lawn and Imrie (1991) found that genetic improvement has been confounded by large and often non-systematic G x E interaction, which increases the testing necessary as a basis for selection. The physiological studies assist the interpretation of G x E interaction in terms of biological as opposed to statistical models.

Zhu (1992) conducted research on 23 varieties of soybeans to study the effect of autumn sowing on the spring soybeans. He evaluated the variety x sowing season interaction, coefficient of genetic variation, heritability, genetic advances and the coefficient of correlation among the agronomic characters of spring soybean sown in autumn and single plant productivity of spring soybean sown in spring. The results indicated that the difference of primary agronomic characters, the difference between sowing season and the variety and the sowing season interaction were significant or highly significant. The effectiveness of direct selection to agronomic character of spring soybean sown in autumn was lower. But the heritability of the 100-seed weight and plant height sown in autumn was higher. The correlation between single plant productivity sown in spring and autumn exhibited highly significant differences.

Soybean with modified fatty acid composition in the seed oil is being considered for commercial production. The stability for fatty acid composition across a range of environmental conditions will be an important factor for end users of the new soybean oils. Schnebly and Fehr (1993) evaluated the influence of the year and sowing dates on the fatty acid composition of 12 soybean genotypes. For the genotypes with elevated palmitic acid, A21, there were significant differences among years, but the maximum difference was only 10g kg^{-1}. Effects of planting dates were not significantly different for the palmitic acid content of A21. For the genotypes with elevated stearic acid, A6, differences among years, planting within individual years, and years x planting dates interaction were significant but the effect of planting dates averaged across years was not significant. Differences among years were significant for the linolenic acid content of most genotypes. Early planting dates favored lower linolenic acid. Average daily high temperature during the seed filling period did not consistently explain the differences in fatty content among planting dates or years.

When a specific cropping system imposes a unique set of environmental factors on a crop, plant breeders will evaluate the usefulness of conducting a separate selection program to produce genotypes specifically adapted to the cropping system. Pfeiffer (2000) studied soybean to determine if tall soybean lines selected from full season plantings were better adapted to double crop planting than lines chosen from the same population with regard to plant height. Four sets of soybean lines, with tall and random height group in each were compared in full season wide row and late planted narrow row cropping system to determine the interaction between plant height and yield in the two different cropping systems.

Soybean grown in the full cropping system yielded an average of 32% more than that grown in the double-cropping system.

PARTICIPATORY PLANT BREEDING (PPB):

Participatory Plant breeding (PPB) involves the close collaboration of the farmers, consumers, industry and breeders in the development of new cultivars. Participatory plant breeding done from the formal plant breeding aspects includes those efforts, which are initiated by or with primary leadership from the formal agricultural research sector. Thus, Participatory Plant Breeding (PPB) refers to the full scope of activities associated with plant genetic improvement which include the identification of breeding objectives, generating genetic variability, selection within variable population, evaluating varieties, variety release, seed production and end use. Beyond the variety development, Participatory Plant Breeding consists of technical education to equity concerns, and to insure collaboration in different research phases. The objectives of such end-user involvement described by Sperling and Ashby (1999) are:

- Relevancy: to bring more demand-driven and client-oriented research and extension
- Representative: to encourage the formal research systems to address a representative range of themes
- Equity: to address concerns of the more marginalized stakeholders
- Research insights: to gain from the technical and social insights of those close to specialized research and development issues
- Ownership: to bring onboard the range of stakeholders needed to encourage the success of a technical innovation and

- Logistical imperatives: to make use of stakeholders, land labor or energy to scale ups the research and development.

In some programs, PPB has led to the recommendation of working through local seed systems and increasing their efficiency and ability to serve a wide range of clients. In the Western region of India, description of locally grown varieties in the target areas has allowed breeders to choose material for testing that differed distinctly from the locally grown varieties for a particular character (Witcombe et al., 1996). Further, farmers played a significant role in the breeding program of pearl millet in the dessert region of Rajasthan. Farmers do not differentiate between varieties but differentiate plant types with specific variables adaptive to specific environmental conditions. Breeding programs targeting this region now work towards offering farmers a range of different types of materials for use in mixed seed lots (Weltzein et al., 1998). Farmers' genetic material can be used in different ways. In many cases, farmers have contributed landraces to be used as parents for crossing or for targeted improvement efforts e.g. a rice landrace in Nepal, tolerant to chilling temperature was crossed with a high yielding, chilling susceptible variety. Farmers have used the progeny from this cross to select a new variety (Sthapit et al., 1996). Landrace varieties are the starting point of the project to enhance farmers' own skill for genetic improvement.

Another important goal of PPB programs is to provide benefits for different types of farmers' e.g. rural poor, women and the farmers with marginal soils. Such a goal necessitates an extensive diagnosis among well-defined potential users and stakeholder groups. PPB programs help to find policy modifications relating to variety release procedures. Modification is needed to accommodate expansion and institutionalization of those approaches that better serve farmers' needs. This modification includes scale of testing, scale of adaptation, and the kind of data required for variety release and number of cultivars released.

Many institutional breeding programs fail to meet the needs and requirements of the farmers under marginal environments. Many plant breeding programs focus on developing cultivars, which have high yield potential under favorable conditions. There are many more marginal environments in which improved cultivars do not express increased yield potential or do not satisfy other use requirements. G x E interaction plays a major role; it involves adaptation to both the physical and socioeconomic environments. This suggests that there is need for a more decentralized breeding approach. The main issue is how users can benefit from these requirements. These requirements can be met through traditional seed system and managing landraces. Such systems are under stress in many regions. Germplasm resources are limited and unsecured while indigenous knowledge and social institutions are being eroded in many parts of the world. Such erosion is due to political instability, wars and escalating aid programs. Therefore, breeding should take into consideration these approaches that will result in the development of genotypes with wide adaptability. The challenge in the breeding program is not limited to marginal environments. The farmer in the better environment may benefit from participation in the breeding process for the same reason as in marginal environments especially wide range of adaptability of cultivars and faster dissemination of products. Thus, participatory breeding is used in a wide context ranging from decentralizing breeding program to various degrees of farmer's involvement (Jaap H. 1995).

In Pakistan, researchers collect germplasm from different sources and evaluate them at their research stations. After evaluation, the germplasm is maintained and different breeding methods are used for the development of cultivars. Due to limited quantity of seed, the preliminary yield trials are conducted at different locations to evaluate their adaptability. Then, on the basis of their adaptability, and availability of seed, National Uniform Yield Trials are conducted at different research stations as well as on the farmers' fields. Thus, on the basis of performance, suitable cultivars are developed and this process continues for three years. Depending upon their potential under different ecological zones, cultivars are selected for commercial production with the recommendations of the farmers. The farmers' field days are organized to demonstrate the improved cultivars.

The government of Pakistan manages all the research stations of agriculture. Administrative decisions, policies, and inadequate funds impact the effectiveness of cultivar development programs. This participatory plant breeding program does not only introduce the development of cultivars according to the farmers' requirement, but also involves the training of the researchers at national and international levels.

In Pakistan about 70% of the total population is engaged in agriculture. An Extension department and Experiment Stations exist in Pakistan but there is very weak coordination and linkage between them. As a result of this, the research being conducted at the experiment stations is not conveyed to the farmers and the farmers do not benefit from this research.

The AoE model will effectively coordinate the research and extension work as the Area of Expertise Teams (AoE) plan, implement and evaluate the educational programs to meet the needs of the targeted problem or opportunity area. Each team will consist of experts, researchers, agents, specialists and extension workers (both from extension and experimentation stations) and selected others like customers, cooperators etc., who can promote the marketing with an interest and expertise in the area of focus. An AoE Team does not have any restriction in size. Each team should include specialists from the university, research institutions and experts from extension department of different disciplines who can communicate with the concerned parties. Stakeholders' involvement in programming is an essential element of the interdisciplinary, problem-solving and customer focus of AoE Teams. Representatives of stakeholder groups invited to the AoE meetings will be provided information on emerging needs and issues facing the industry and the interested groups. These AoE Teams are expected to be self-directed in all aspects of their educational programming throughout the country. The Teams will be involved in assessing and prioritizing customer needs, mentoring new team members and developing team expertise, and planning and implementing an educational response to meet their needs.

The concept of self-directed teams evolved from a need to improve organizational performance in both private and public sectors. Traditional vertically and hierarchically structured organizations have been considered too slow and cumbersome in responding to changing conditions and competition (Deeprose, 1995; Fisher, 1993; Orsburn, Moran, Musslewhite, & Zenger 1990). Such organizations often lack involvement and creativity and fail to take advantage of perspective, expertise, and creativity of the employees providing products and services to the clients, whereas self-directed work teams place decision-making and problem-solving authority in the hands of the persons closest to the product or services being created and provided (Orsburn, et al., 1990; Quick, 1992; Wellins, Byham & Wilson, 1991). The private organizations made great achievements by self-directed teamwork because productivity was enhanced and resulted in more consumer satisfaction.

The adoption of AoE Teams and related system changes in Michigan (USA) created the seamless interface between Extension and Experimentation Station resulting in increased capacity to deliver quality educational programs. Suvedi (1996) studied 1600 producers in Michigan and found that more than half of Michigan farmers heard about AOE teams and irrespective of farm type, education or income level, they expressed satisfaction with the Extension work. Leholm et al., (1999) reported in this model in the "Area of Expertise Team: The Michigan Approach to apply "Research and Extension". The AoE Team approach helped develop and deliver quality applied research and extension programs to the farmers. The AoE Teams have made it possible to eliminate much of the extension mid-level management and transferred those resources to team support. The AoE approach, which connects field, campus, and stakeholders, and ties research to extension with interdisciplinary, problem-solving focus, has produced results that improve peoples' lives. Feedback both from campus as well as from staff members has been very encouraging. Because of AoE, motivation was enhanced among field staff members, strong credibility was translated into renewed pride among many stakeholders for their land grant university, and this help assures continued public support into the 21st century.

Agricultural Extension departments and Experimentation stations exist in Pakistan but there is very weak coordination and linkage between research conducted at the station and its dissemination to the farmer in an effective time and manner. Because of this, the research being conducted at the experiment stations does not reach the farmer and the farmers do not benefit from this research in a timely fashion. A model can be developed where AoE teams can serve as a bridge between the researcher and the farmer. This will result in a strong linkage between the Extension and Experiment stations and the latest production technology and information can be disseminated to the farmer's end users at the proper time. These AoE Teams, which will consist of experts from extension departments, research institute and universities, can help promote this link in different disciplines. Through developing this model in Pakistan, it is expected that the agricultural production will be increased due to better education and dissemination of information. Thus, the production and consumption gap can be reduced in most of the commodities, which at present are being imported to meet the needs of the country. These imports are a burden on the national exchequer on which a huge amount of foreign exchange is spent.

These plant breeding programs focus on developing cultivars for high yield potential under favorable conditions only. There are many more marginal environments in which improved cultivars do not express increased yield potential or do not satisfy other use requirements. G x E interaction plays a major role; it involves adaptation to physical and socioeconomic environments. This suggests the need for a more decentralized breeding approach. The main issue is how users can benefit. These requirements can be met through traditional seed systems and managing land races. Such systems are under stress in many regions. Genotype resources are limited and unsecured while indigenous knowledge and social institutions are being eroded in many parts of the world, which is due to political instability, wars and escalating aid programs. Therefore, a breeding program should take into consideration the approaches that will result in the development of genotypes with a wide range of adaptability. The challenge in the breeding program is not limited to marginal environments. The farmers in the better environments may also benefit from participation in the breeding process for the same reason as in marginal environments, especially with wide range of adaptability of cultivars and faster discrimination of products. Thus, participatory breeding can be used in a wide context ranging from decentralizing breeding programs to various degrees of farmer's involvement (Jaap H. 1995).

In Pakistan, the government manages all the research stations of agriculture. Administrative decisions, policies, and inadequate funds influence the effectiveness of cultivar development programs. Thus, a participatory plant breeding program not only introduces the development of cultivars according to the farmers' needs, but also involves the training of the researchers at national and international levels which also involves availability of funds. If decentralized and non-government organizations are involved in an open competition, there will be more progress and participation combined with decentralization that will help the farmers:

- To meet the needs of a diversified environment in order to manage risks.
- To satisfy different users and uses

A participatory program also allows the farmers to meet their individual needs, which vary because of difference in wealth distribution and agronomic conditions and practices on their farms. In general, there is a greater use of plant genetic diversity in participatory plant breeding. This is important in overcoming limits on productivity in reducing the chemical inputs in the more favored area and developing crop varieties for the marginal areas.

The area of Expertise (AoE) model created and used in Michigan has been found very successful due to its achievements. A similar model with some modifications according to the needs of the users can be developed in Pakistan, which will result in a strong link between Extension and agricultural researchers. As a result, extension workers can help develop the research agenda and the latest production technology or information will be disseminated to the farmers. Thus, the production and consumption gap can be reduced in most of the commodities, being imported to meet the needs of the country, and on which a huge amount of foreign exchange is being spent.

MATERIALS AND METHODS

CHAPTER-III

MATERIALS AND METHODS

EXPERIMENTAL MATERIALS AND METHODS:

In Pakistan, soybeans are planted in both rainfed and irrigated areas during autumn and spring. In the Fatehjang area, soybeans can be planted only during autumn due to high rainfall and land availability. Soybeans can be grown in autumn and spring (Hobbs, et al. 1984) at the National Agricultural Research Center in Islamabad. Multan, a cotton area of Southern Punjab, and Gujranwala, a rice area of central Punjab, were identified as potential areas for soybean production due to availability of land and irrigation. These locations have different rainfall patterns and temperatures during the crop production period. Nine soybean genotypes were selected based on traits such as maturity, type of growth habit, plant height, 100-seed weight, pod height, oil and protein percentage and yield. They were 1. 'NARC-IV' (III) 2. 'FS-85' (II) 3. 'Harper' (III) 4. 'NARC-V' (III) 5. 'Swat-84' (III) 6. 'Williams-82' (III) 7. 'Weber' (I) 8. 'NARC-III' (III) 9. 'Century-84' (II). 'Williams-82', the most widely grown cultivar, was used as a standard genotype for baseline comparison purposes. All these cultivars were introduced and 'NARC-III', 'NARC-IV', and 'NARC-V' were selected from 'PSC-58', 'PSC- 61' and 'PSC- 59' respectively. The study has some inherent limitations due to the small number of soybean cultivars; Weber, Group (I), Century-84 and FS-85 Group (II) and Harper, NARC-III, NARC-IV and NARC-V, Swat-84 and Williams-82 Group (III). In order to minimize bias, the experimental material was coded and then decoded after the data collection.

In autumn 1992,1993 and 1994, experiments were conducted on clay loam soil, suitable for crop production at two locations, Islamabad and Fatehjang. In the spring season of these same years, experiments were conducted at three locations; Islamabad and Gujranwala on silt clay and Multan on silt clay loam soil.

The temperature and rainfall for the four locations are given in Table 7A, 8A, 9A, and 10A. At all locations and seasons, a randomized complete block design was used with four replications. Plot size was standardized to four rows 5 meter long. Row spacing in the autumn was 45 cm while 30 cm was used in spring season because of increased vegetative growth of the crop in autumn. Artificial inoculum (*Rhizobium japonicum*) was used to inoculate the soybean seed at all locations and years. Plant spacing was 3-5 cm in each season and location. Recommended cultural practices were followed throughout the growth period of the crop. Plots were hand weeded according to need. Diammonium phosphate (18-46-0) and urea (46-0-0) were applied to provide a total of 50 kg N and 60 kg P per ha. All the DAP and half of the urea were incorporated at the time of planting. The remaining half of the urea was applied when the crop was in flowering stage.

In the autumn seasons, seeds were planted in the first and second week of July at Islamabad and Fatehjang following wheat each year and in the spring seasons, seeds were sown after sunflower on the last week of January at Islamabad while planting occurred after rice on the second week of February at Gujranwala and after cotton at Multan. These planting times were considered optimum for yield performance (Table 6A).

In the autumn, rain provided adequate moisture at Islamabad and Fatehjang, whereas in spring seasons, supplement irrigation methods was needed for good seed production at Islamabad, Multan and Gujranwala because rainfall was limited. Irrigation was applied

(i) three weeks after germination, (ii) at initiation of flowering, (iii) at pod formation, and (iv) during seed development.

DATA RECORDING PROCEDURE:

Data from the following traits were recorded at the appropriate time:

Days to flowering

Days to flowering (50% of the plants were in flower) were calculated as the number of days from sowing until flowering.

Maturity

Data were recorded when 95 % of the pods in a plot were matured (turned brown).

Plant height (cm) at maturity

Five plants randomly selected from each plot were tagged and their heights were measured from the soil surface to the apex. The same plants were used for future measurements of various agronomic characteristics.

Pod height (cm)

Pod height was measured as the distance from the soil surface to the first matured pod.

Pods per plant.

Matured pods on the main stem and on all branches were counted when plants were physiologically matured.

Seeds per pod

Five pods from each of the five plants were threshed, the seeds were counted, and the average number of seeds was computed.

100-Seed weight (g)

After obtaining the seed yield, 100 seeds were randomly selected from each plot and weighed.

Percentage oil

Samples (two samples, 20gm each) from each plot at each at location and in each year were analyzed to determine oil content at the National Agricultural Research Center Oil Technology Laboratory using nuclear magnetic resonance (NMR) and averages were computed.

Percentage protein

Two samples (20 gm each) from each plot at each location and year were analyzed and averages were computed to determine protein content at the National Agricultural Research Center Oil Technology Laboratory using the Kjeldahl's method.

Seed yield

Two central rows of each plot were harvested and the plants were dried in the sun for 4-6 days. This material was manually threshed and cleaned separately at each location and year. Seed yield of each plot was weighed and moisture content was recorded by using the moisture tester. Plot yield was converted to yield kg ha$^{-1,}$ adjusted at 13 % moisture content by using the following formula:

Yield kg ha^{-1} at 13% moisture content

$$= \text{Plot yield (kg)} \times \frac{1000}{\text{Harvested area}} \times \frac{100 - \text{\% of moisture}}{87}$$

STATISTICAL PROCEDURE:

GENTOTYPE x ENVIRONMENT INTERACTION MODEL:

In order determine the G x E interaction, the following model was used:

$Y_{ijkml} = \mu + g_i + b_j + e_k + c_m + (gb)_{ij} + (ge)_{ik} + (gc)_{im} + (be)_{kj} + (bc)_{jm} + (gbc)_{ijm} + (gbe)_{ijk} + error_{ijkml}$

where Y_{ijkml} is the l^{th} observation at the i^{th} variety j^{th} year k^{th} season and m^{th} location, μ is the grand mean, g_i is the effect of i^{th} variety, b_j is the effect of j^{th} year, e_k is the effect of k^{th} season, c_m is the effect of m^{th} location, $(gb)_{ij}$ is the interaction between variety and year effects, $(ge)_{ik}$ is the interaction between variety and season effects, $(gc)_{im}$ is the interaction between variety and location, $(be)_{kj}$ is the interaction between year and season effects, $(bc)_{jm}$ is the interaction between year and location effects, $(gbc)_{ijm}$ is the three way interaction among variety, year and location effects, $(gbe)_{ijk}$ is the three way interaction among variety, year and season and $error_{ijkml}$ is the normally distributed random variable with mean 0 and variance σ^2.

The stability model as suggested by Eberhart and Russell (1966) was used in the regression of each variety in an experiment on an environmental index and a function of the squared deviations from this regression provided estimates of the desired stability parameters that are defined by using the following model:

STABILITY MODEL:

Mean:

$$Y_{ij} = \mu_i + \beta_i I_j + \delta_{ij}$$

where Y_{ij} is the variety mean of the i^{th} variety at j^{th} environment, μ_i is the mean of the i^{th} variety over all the environments, β_i is the regression coefficient that measures the response of the i[th] variety to varying environment, δ_{ij} is the deviation from regression of the i[th] variety at j[th] environment and I_j is the environmental index obtained as the mean of all varieties at the j[th] environment minus the grand mean:

$$I_j=\sum_i \frac{Y_{ij}}{v}-\sum_i \sum_j \frac{Y_{ij}}{vn} \quad \text{and} \quad \sum_j I_j=0$$

Regression coefficient:

$$b_i=\frac{\sum_j Y_{ij} I_j}{\sum_j I_j^2}$$

The performance of each variety can be predicted by using the estimates of the parameters where $\hat{Y}_{ij}=\bar{X}_i+b_i I_j$ and $\bar{X}_i$ is an estimate of the μ_i. The deviations $[\delta_{ij}=(Y_{ij}-\bar{Y}_{ij})]$ can be squared and summed to provide an estimate of another stability parameter: $(\sigma^2_{d_i})$.

Deviation from regression:

$$s^2_{d_i}=\sum_j \frac{\delta^2_{ij}}{n-2}-\frac{s^2_e}{r}$$

where $\frac{s^2_e}{r}$ is the estimate of the pooled error (or the variance of a variety mean at the j[th] location) and: $\sum_j \delta^2_{ij}=\left[\sum_i Y^2_{ij}-\frac{Y^2_{i.}}{n}\right]-\frac{\left(\sum_j Y_{ij} I_j\right)^2}{\sum_j I_j^2}$

Genotype coefficient of variation:

$$CV_i=\frac{s_{d_i}}{\bar{Y}_i}\times 100$$

PARTICIPATORY PLANT BREEDING MODEL:

In Pakistan and other developing countries, a new model of cultivar development is needed to make Pakistan globally competitive in soybean production. The model will address three critical issues for the breeding program; (i) priority setting, (ii) sustainable funding and (iii) participatory planning and implementation.

(i) Priority setting:

Selection of appropriate breeding objectives/priorities is essential for a successful breeding program. How these breeding priorities are determined will play an important role in determining the impact of the breeding program.

(ii) Sustainable funding:

Funding is an important part of a successful breeding program. Finding ways to access sufficient sources of public and private funds will determine the type of breeding program that can be accomplished.

iii) Participatory planning and implementation:

Effective coordination of research and its extension linkage is important to the success in bringing new vareities and an updated knowledge base to its end user, the farmer. The model for the breeding program must outline a procedure where the plant breeders have effective communication links to the farmers, markets, industry and the consumers. This model will describe how the farmers, industries and consumers will handle information to insure that the cultivars that are developed will be appropriate and utilized.

A participatory plant breeding model will be developed that will take into consideration the socio-cultural norms of Pakistan. It will outline procedures, which will encourage clientele to take ownership in the soybean-breeding program. The model will help mold a breeding program that is competitive with other soybean breeding programs in the region.

Keeping in view the importance of the development of new soybean cultivars in Pakistan and the significance of bridging the production and consumption gap of edible oil, the study of genotype x environment interaction and stability for yield and its components in soybean cultivars was conducted in Pakistan with the following objectives:

- To estimate variability for different agronomic traits (days to flowering, plant height, pod height, pods per plant, maturity, seeds per pod, 100-seed weight, oil and protein percentage, and seed yield) at 4 different locations and over 3 years.
- To identify suitable and optimum locations/areas (cotton, rice, and rain-fed) in Pakistan for soybean production.
- To identify stable and high yielding cultivars through estimation of different stability parameters under different ecological conditions in Pakistan.
- To outline a soybean breeding strategy that incorporates participatory breeding principles. This breeding strategy can serve as a model for other breeding programs in both the developing and developed world.

RESULTS AND DISCUSSION

CHAPTER-IV

RESULTS AND DISCUSSION

GENOTYPE X ENVIRONMENT INTERACTION AND STABILITY:

The importance of genotype x environment (G x E) interaction in crop improvement has been known for decades (Hanson, 1970). In the presence of genotype x environment interaction, relative ranking of genotypes and the magnitude of genetic difference between genotypes changes from one environment to another. However, this interaction presents a major problem in comparing the performance of a large number of genotypes across environments. Statistical methods for assessing the stability of genotypic performance in different environments are necessary to help the plant breeder in the selection of superior cultivars for a specific type of environment.

The interpretation of data consists of determining the statistical significance of sources of variation and assessing variation observed among mean values. The genotype x location interaction measures the stability of performance among the genotypes at different locations. Wide fluctuations in the rank performance of genotypes at different test locations allow the selection of genotypes for different locations. The genotype x year interaction measures the consistency of performance among genotypes during different years. An inconsistent ranking performance among genotypes planted in different years is more difficult to deal with than is a genotype x location interaction. The only option is to select genotypes, which show superior performance across years. This involves the testing of genotypes in several years before selection for release as commercial cultivars. In order to reduce the time for the evaluation of a genotype, multiple locations can be used as a substitute for years. However, the substitution is effective only if the difference in climatic conditions among locations is comparable to climatic differences among years. The genotype x location x year interaction measures the stability of performance among genotypes for each combination of year and location. A significant genotype x location x year interaction means that the relative performance among genotypes was not the same for each of the year and location combinations. When there are fluctuations in the ranking of genotypes associated with individual location x year combinations, the breeder must select genotypes with superior average performance over locations and years, which can be accomplished by evaluating over multiple locations and years. The implication of significant genotype x environment interactions depends on the cause of the interaction. Genotype x environment interactions is not a problem for the plant breeder if they are not due to changes in rank of performance among genotypes. The same cultivars would be superior in all locations and years but superiority may vary. Significant genotypes x environment interaction, which cause changes in rank performance, are commonly observed. In order to determine the implication of interactions, the breeder must consider the extent of the changes in rank and their potential impact on genetic improvement.

Horner and Frey (1957) evaluated oat genotypes in the state of Iowa by dividing the state into four different regions. Cultivars x location interactions were determined for various combinations of nine locations and five years. The combinations with the lowest cultivar x location mean squares were the most suitable regions within Iowa for oat cultivation.

The stability of genotype performance over the locations and years is very important for the development of genotypes. Some cultivars are suited to a broad range of environmental conditions while others are limited in their potential areas. Some genotypes perform similarly regardless of the production level of the environment while the performance of others is directly related to the productivity level of the environment.

The results below are discussed based on each character selected for stability parameters. Table 1. shows the mean and ranking of 9 soybean cultivars for days to flowering, days to maturity, plant height (cm), pod height (cm), pods per plant, seeds per pod, 100-seed weight (g), oil percentage, protein percentage and yield (kg/ha) during autumn 1992, 1993 and 1994. Table 2. Shows the mean and ranking of 9 soybean cultivars for days to flowering, days to maturity, plant height (cm), pod height (cm), pods per plant, seeds per pod, 100-seed weight (g), oil percentage, protein percentage and yield (kg/ha) during spring 1992, 1993 and 1994.

Days to Flowering:

The analysis of variance for days to flowering presented in Table3 reveals highly significant ($P < 0.01$) differences among cultivars, locations, years and their interactions. This indicates considerable variability in days to flowering among cultivars for their response toward different environments (both locations and years). The results indicate which cultivars are genetically early flowering and this variable should be integrated into the desirable cultivars. The planting date will affect the flowering of cultivars. Soybean planted in spring will flower late compared to those planted in autumn due to temperature at the time of planting, but the early cultivars will remain constant in both seasons which indicates genetic differences. Pookpakadi and Siripresert (1986) suggested that unknown climatic

Table. 1. Mean (M) and ranking (R) of 9 soybean cultivars days to flowering (DF 50%), days to maturity (DTM), plant height (pl ht.cm), Pod height (pdht cm), pods per plant (pods/pl), seeds per pod (sds/pd), 100-seed weight (100swt.g), oil percentage (oil %), Protein percentage (prt.%) and yield (yd kg/ha) during autumn 1992, 1993 and 1994.

	DF (50%)		DTM		Plht		Pdht		Pods/pl		Sds/pd		100Swt		Oil(%)		Prt.(%)		Yd(kg/ha	
Cultivar	M	R	M	R	M	R	M	R	M	R	M	R	M	R	M	R	M	R	M	R
Century	30	8	92	8	88	8	7	4	30	8	3	4	18	6	20.9	3	40.2	8	2043	8
FS-85	31	7	92	7	89	7	7	3	32	6	3	3	18	7	20.8	7	40.3	6	2198	4
Harper	34	5	96	1	93	2	7	2	33	5	3	1	19	4	20.9	4	40.5	4	2174	6
NARC-III	32	6	96	4	93	3	6	7	36	2	3	2	19	1	20.9	5	40.9	3	2462	3
NARC-IV	37	1	96	5	93	4	6	5	37	1	3	2	19	2	20.9	6	40.9	2	2564	1
NARC-V	36	2	96	3	94	1	6	8	36	3	3	4	19	3	20.9	2	41.0	1	2509	2
Swat-84	35	3	96	2	92	5	8	1	33	4	3	4	18	9	21.3	1	40.3	5	2175	5
Weber	28	9	83	9	81	9	6	6	28	9	3	3	18	7	20.8	9	40.2	7	1910	9
William-82	35	4	95	6	92	6	7	2	32	7	3	3	18	5	20.8	8	39.1	9	2148	7
Std.error	0.55		0.67		1.52		0.42		0.87		0.24		0.35		0.17		0.11		35.90	

Table 2. Mean (M) and ranking (R) of 9 soybean cultivars days to flowering (DF 50%), days to maturity (DTM), plant height (pl ht.cm), Pod height (pdht cm), pods per plant (pods/pl), seeds per pod (sds/pd), 100-seed weight (100swt.g), oil percentage (oil %), Protein percentage (prt.%) and yield (yd kg/ha) during spring1992, 1993 and 1994.

	DF (50%)		DTM		Pl ht		Pd ht		Pods/pl		Sds/pd		100Swt		Oil(%)		Prt. (%)		Yd (kg/ha	
Cultivar	M	R	M	R	M	R	M	R	M	R	M	R	M	R	M	R	M	R	M	R
Century	58	8	123	8	58	8	4	8	25	8	3	5	17	7	20.8	7	40.2	8	1876	8
FS-85	60	7	124	7	60	7	4	6	26	7	3	2	18	5	20.8	7	40.3	7	1888	6
Harper	62	5	126	5	61	5	5	4	28	4	3	6	18	3	21.1	2	40.4	6	1929	5
NARC-III	63	2	127	2	62	3	5	1	30	3	3	4	18	2	21.3	1	40.9	2	2049	2
NARC-IV	64	1	126	4	62	2	4	5	30	2	3	3	18	1	20.9	5	40.8	3	2038	3
NARC-V	62	4	127	3	62	1	4	2	30	1	3	3	18	2	21.0	3	40.9	1	2060	1
Swat-84	62	6	127	1	67	4	4	5	28	5	3	1	18	3	20.9	4	40.5	5	1945	4
Weber	54	9	118	9	54	9	4	7	25	9	3	2	17	2	20.9	6	40.1	9	1853	9
William-82	62	3	126	6	60	6	4	3	27	6		4	18	4	20.9	5	40.6	4	1880	7

Std.error 0.69 1.15 1.55 0.41 1.11 0.22 0.20 0.14 0.13 58.8

and environmental conditions contributed to the differences among years. There were significant differences among locations among years for days to flowering. The relative importance of years and locations would be expected to vary among studies because of variation in the uncontrolled climatic conditions. Wang and Murphy (1994) considered the year effects to be more important than location effects in their research. The genotype x environment interaction when split into predictable and non-predictable components showed the importance for both types of variation for all sets of analysis. Pathak and Nema (1984), and Chan et al. (1986) also reported the importance of genotypic variance as influenced by the environmental index.

During autumn, all the genotypes took less time to flower. Highly significant differences among genotypes and environments (Table 3) indicate variability among both cultivars and the environments. The environment influenced the character differently, as indicated by a highly significant ($P<0.01$) variance due to environment components. Century-84, FS-85, NARC-III and Weber cultivars, flowered less than the average time (33 days). These four genotypes had a regression coefficient of less than one and the low deviation from regression. (Table 4). Hence these could be considered as early genotypes.

During spring (Table 5) Century-84 and FS-85 flowered in less than the average number of days (61 days) with regression coefficients 1.18 and 1.29 respectively indicating the influence of genetic control. Harper and Williams-82 had regression coefficients above one with high means. Chan, et al. (1986) observed continuous variation in results but differed among locations, deviation from regression for days to flowering tended to increase from South to North. Mayers et al., (1991) observed variation in photothermal regime across site, year and sowing date with the tropical dry season.

In the overall analysis (Table 6) there was very little variation in the regression coefficient. Harper and NARC-III flowered in 51 and 50 days, respectively, with regression coefficients of 1.03 and 1.11 with low deviation from regression (0.65 and –0.51) respectively. Thus, these two cultivars might be considered stable genotypes for days to flowering. In addition, there are other cultivars, NARC IV and SWAT-84, that have means above the average (50days) with regression coefficients 0.974 and 0.962 and low deviation from regression –1.15 and –1.32, respectively. This indicates that they are genetically late and stable genotypes.

It is concluded from the data that Weber is the earliest to flower; the most stable due to a regression coefficient close to one and had the lowest deviation from regression. Thus, as the most stable variety, its early flowering will be helpful for early maturity and will be less effected by drought than the late flowering cultivars in both rainfed and irrigated areas. The early flowering cultivars will be used in the breeding program, which fit into the cropping system in Pakistan.

Table 3. Analysis of variance of 9 soybean cultivars, 3 years and 4 locations for days to flowering (50%) of autumn, spring and overall during 1992, 1993 and 1994.

	AUTUMN		SPRING		OVERALL	
SOURCE	DF	F value	DF	F value	DF	F value
Year (Y)	2	31.3**	2	194.7**	2	24.9**
Location (L)	1	30.4**	2	1880.8**	3	118.1**
Y x L	2	29.6**	4	105.9**	6	32.8**
Cultivar (C)	8	158.7**	8	62.1**	8	238.7**
Y x C	16	16.5**	16	2.3**	16	10.6**
L x C	8	5.6**	16	4.1**	24	8.5**
C x L x Y	16	4.3**	32	2.6**	48	4.1**
Season (S)	-	-	-	-	1	8436.2**
Y x S	-	-	-	-	2	61.5**
S x C	-	-	-	-	8	19.5**
Y x S x C	-	-	-	-	16	7.8**

** Significant at 0.01 probability level

- **Y** = Year
- **L** = Location
- **C** = Cultivars
- **S** = Season

Table 4. Stability parameters [mean, regression coefficient (b) and deviation from regression S^2d)] of 9 soybean cultivars for days to flowering (50%) planted at 2 different locations during autumn 1992, 1993 and 1994.

Cultivars	Mean	b	S^2d
CENTURY-84	31	0.35	-1.41
FS-85	31	0.07	0.56
HARPER	34	0.21	1.99
NARC-III	32	0.66	-2.01
NARC-IV	37	0.57	-1.48
NARC-V	36	2.07	1.43
SWAT-84	35	1.46	-1.29
WEBER	28	0.96	0.06
WILLIAM-82	35	2.65	2.21

Mean	33
Std. error	0.23
CV	4.56

Table 5. Stability parameters [mean, regression coefficient (b), deviation from regression (S^2d)] of 9 soybean cultivars for days to flowering (50%) at 3 different locations during spring 1992, 1993 and 1994.

Cultivar	Mean	b	S^2d
CENTURY-84	58	1.18	0.31
FS-85	60	1.29	0.25
HARPER	62	1.27	-0.05
NARC-III	63	0.83	0.23
NARC-IV	64	0.93	-0.53
NARC-V	62	0.63	0.73
SWAT-84	62	0.94	-1.00
WEBER	54	0.88	0.63
WILLIAM-82	62	1.05	-0.56

Mean	61
Std.error	0.24
CV	2.25

Table 6. Overall stability parameters [mean, regression coefficient (b) and deviation from regression (S^2d)] of 9 soybean cultivars, 4 locations, and 2 seasons for days to flowering (50%) during 1992, 1993 and 1994.

CCULTIVARS	**Mean**	**b**	**S^2d**
CENTURY-84	47	1.01	-0.43
FS-85	48	1.04	0.53
HARPER	51	1.03	0.65
NARC-III	50	1.11	-0.51
NARCI-V	53	0.97	-1.15
NARC-V	52	0.95	1.35
SWAT-84	51	0.96	-1.32
WEBER	44	0.93	-0.11
WILLIAMS-82	51	0.99	0.98

Mean	50
Std.error	0.61
CV	2.98

Days to maturity:

Days to maturity is a very important variable for selecting genotypes for the different agroecological zones and different cropping systems in Pakistan. Several maturity types are needed to fit the different cropping systems. However, short season cultivars fit better into the different cropping systems in Pakistan.

The pooled analysis of variance for days to maturity at 4 locations in 3 years (1992-94) during spring and autumn and overall is presented in Table 7. Highly significant differences among cultivars, location, years and their interactions were found indicating the presence of variability and sensitivity of cultivars to different environments. Similar results were observed by Cianzio et al., (1991). Estimated variance due to environment (linear) was much greater than the estimate of genotype effect, hence made a greater contribution to the total estimated variance (Naidu et al., 1991). Days to maturity is highly affected by the season: during the autumn, the crop takes less time to mature. The cultivar x location, cultivar x year, and cultivar x year x location interactions were highly significant; they were also significant when tested against pooled deviation, which revealed that there are real differences among varieties for their regression on the environmental index. However, the present investigation clearly indicates that days to maturity was affected more by the environmental fluctuation. The regression coefficient ranged from 0.17 to 1.79, which showed instability for this trait in soybean during autumn (Table 8). Cultivars NARC-III and NARC-IV had mean values greater than grand mean and regression coefficients less than one indicating that these cultivars are stable under unfavorable environments. Cultivars Harper, NARC-V, SWAT-84 and William-82 had means greater than the grand mean and regression coefficients more than one; therefore, these cultivars are stable for late maturity.

During autumn, the mean of days to maturity ranged from 83 to 96 days with regression coefficients values form 0.17 to 1.79 along with varying degrees of deviation from regression (-1.54 to 1.96) which revealed that days to maturity is really difficult to predict.

During spring (Table 9), the cultivars took more days to mature compared to the autumn season along with significant differences among genotypes- environments (location, year and their interaction). The mean values of the cultivars ranged from 118 to 127 days to maturity and regression coefficient value ranged from 0.97 to 1.06 with low to high deviations from regression (-1.44 to 2.71). For individual comparison of genotypes it was observed that Harper, NARC-III, NARC-IV, NARC-V, Swat-84 and William-82 had mean values more than the grand mean and regression coefficients close to one which shows the stability of the cultivars under all environments. Cultivars Century-84, FS-85 and Weber had regression coefficients close to one but they are associated with lower means than grand mean, therefore, these cultivars are stable for early maturity. This indicates that these cultivars showed less sensitivity to different environments (Harer and Shahi 1991).

The stability parameters for all the sites (Table 10) indicate that Harper, NARC-III, NARC-IV, NARC-V Swat-84 and Williams-82 had above average (112) days to maturity. These cultivars possessed regression coefficients close to one which indicate that they are generally stable to all environments, whereas Century-84, FS-85 and Weber matured earlier than the average performance of all the cultivars overall (112) days but the regression coefficients of these cultivars is close to one which shows that these are stable.

Maturity is one of the most important variables to be considered when developing new cultivars. Early maturing cultivars will fit into the multi-cropping systems of developing countries like Pakistan where water-holding capacity is low and short duration cultivars are required to increase the cropping intensity. The short duration cultivars like Weber, Century-84 and FS-84 should be utilized in the breeding program in Pakistan for the development of cultivars suitable for the different cropping systems.

Table 7. Analysis of variance of 9 soybean cultivars, 3 years and 4 locations for days to maturity of autumn, spring and overall during 1992, 1993 and 1994.

	AUTUMN		SPRING		OVERALL	
SOURCE	**DF**	**F value**	**DF**	**F value**	**DF**	**F value**
Year (Y)	2	23.0**	2	194.9**	2	118.9**
Location (L)	1	92.2**	2	1880.8**	3	1904.4**
Y x L	2	92.6**	4	105.9**	6	109.6**
Cultivar(C)	8	232.9**	8	62.1**	8	176.9**
Y x C	16	7.18**	16	2.3**	16	5.9**
L x C	8	13.4**	16	4.1**	24	5.9**
C x L x Y	16	5.3**	32	2.6**	48	3.21**
Season (S)	-	-	-	-	1	12215.3**
Y x S	-	-	-	-	2	88.8**
S x C	-	-	-	-	8	10.1**
Y x S x C	-	-	-	-	16	2.9**

** Significant at 0.01 probability level

- **Y** = Year
- **L** = Location
- **C** = Cultivar
- **S** = Season

Table 8. Stability parameters [mean, regression coefficient (b) and deviation from regression (S^2d)] of 9 soybean cultivars for days to maturity planted at 2 different locations during autumn 1992, 1993 and 1994.

CULTIVARS	Mean	b	S^2d
CENTURY84	92	0.32	1.15
FS-85	92	0.51	-0.51
HARPER	96	1.43	0.18
NARC-III	96	0.17	1.96
NARC-IV	96	0.28	-0.61
NARC-V	96	1.77	0.92
SWAT-84	96	1.52	-0.84
WEBER	83	1.22	-0.69
WILLIAM-82	95	1.79	-1.54

Mean	94
St.error	0.32
CV	0.46

Table 9. Stability parameters [mean, regression coefficient (b) and deviation from regression (S^2d)] of 9 soybean cultivars for days to maturity planted at 2 different locations during spring1992, 1993 and 1994.

CULTIVARS	Mean	b	S^2d
CENTURY-84	123	1.01	-1.38
FS-85	124	0.98	1.59
HARPER	126	0.97	-0.74
NARC-III	127	1.02	0.82
NARC-IV	126	0.98	-1.44
NARC-V	127	0.97	0.15
SWAT-84	127	1.00	-0.51
WEBER	118	1.06	2.71
WILLIAM-82	126	0.99	-1.2

Mean	125
Std.error	0.87
CV	1.45

Table 10. Overall stability parameters [mean, regression coefficient (b) and deviation from regression (S^2d)] of 9 soybean cultivars, 4 locations, and 2 seasons for days to maturity during 1992, 1993 and 1994.

CULTIVARS	Mean	b	S^2d
CENTURY-84	110	0.99	-0.31
FS-85	111	0.99	0.47
HARPER	114	0.96	-0.63
NARC-III	114	1.00	1.44
NARC-IV	114	0.98	-0.91
NARC-V	114	0.98	0.61
SWAT-84	115	1.00	-0.79
WEBER	104	1.09	0.96
WILLIAM-82	113	0.99	-0.84

Mean.	112
Std.error	0.85
CV	1.54

Plant height (cm):

Plant height is affected by season as well as by year and location (Table 11). The pooled analysis of variance of cultivars, location, year and their interaction exhibit significant and non-significant results during spring, autumn and overall. Interactions year x cultivar and cultivar x location x year were found to be non-significant during autumn, spring and overall while year was significant during spring and non-significant in autumn. Overall analysis of variance for plant height at maturity also indicates non-significant as well as significant results. In overall analysis, year, year x cultivar and year x location x cultivar were non-significant. Similar results have been reported by Mebrahtu et al., (1991).

Stability parameters estimated for plant height (Table 12) during autumn indicate that Harper, NARC-III, NARV-IV and NARC-V have regression coefficients < 1 which provide a measure of greater resistance to environmental change. Swat-84 and Williams showed regression coefficients > 1 with a mean greater than grand mean indicating increasing sensitivity to environmental change. NARC-III, NARC-IV and NARC-V had means above the grand mean and regression coefficients < 1 (Table 13). Ala (1990) stated that plant height was the most stable trait in maternal varieties while hybrids had higher coefficients of variance than standard cultivars. In the overall stability parameters (Table 14), the genotypes Harper, NARC-III, NARV-IV and Williams-82 were more stable under all environments demonstrated for their regression coefficients about 1 while Century-84, FS-85 and Weber were short stature than the grand mean and had regression coefficients < 1.

Plant height is a very important parameter for any soybean cultivar, if a cultivator is too tall, it will lodge, thus reducing the yield. Therefore, a major objective for the development of soybean cultivar is short stature. Weber, Century-84 and FS-84 have been found stable for short stature, therefore, these cultivars will be included in the breeding program for the incorporation of this variable in the development of a cultivar for potential regions in different cropping systems.

Table 11. Analysis of variance of 9 soybean cultivars, 3 years and 4 locations for plant height (cm) of autumn, spring and overall during 1992, 1993 and 1994.

	AUTUMN		SPRING		OVERALL	
SOURCE	**DF**	**F value**	**DF**	**F value**	**DF**	**F value**
Year (Y)	2	3.01NS	2	9.2**	2	1.5 NS
Location (L)	1	6.99*	2	52.8**	3	39.8**
Y x L	2	5.16**	4	12.1**	6	9.9**
Cultivar (C)	8	43.38**	8	27.6**	8	57.8**
Y x C	16	0.76NS	16	1.2NS	16	0.41NS
L x C	8	3.47**	16	1.8*	24	2.3**
C x L x Y	16	1.6 NS	32	1.0NS	48	1.2NS
Season (S)	-	-	-	-	1	3182.9**
Y x S	-	-	-	-	2	11.5**
S x C	-	-	-	-	8	3.9**
Y x S x C	-	-	-	-	16	1.78NS

* Significant at 0.05 probability level
** Significant at 0.01 level
- **Y** = Year
- **L** = Location
- **C** = Cultivar

S = Season

Table 12. Stability parameters [mean, regression coefficient (b) and deviation from regression (S^2d)] for plant height (cm) of 9 soybeans at 2 different locations during autumn 1992, 1993 and 1994

CULTIVARS	Mean	b	S^2d
CENTURY-84	88	1.63	-1.48
FS-85	89	0.53	0.90
HARPER	94	-0.29	2.69
NARC-III	93	0.33	1.30
NARC-IV	93	0.26	-0.19
NARC-V	94	0.11	0.66
SWAT-84	92	1.68	1.25
WEBER	81	1.92	-1.20
WILLIAM-82	92	2.83	-1.34

Mean	91
Std.error	0.34
CV	1.78

Table 13. Stability parameters [mean, regression coefficient (b) and deviation from regression (S^2d)] of 9 soybean cultivars for plant height (cm) of 3 locations during spring 1992, 1993 and 1994.

CULTIVARS	Mean	b	S^2d
CENTURY-84	58	1.27	-0.88
FS-85	59	1.07	1.26
HARPER	61	1.35	1.98
NARC-III	62	0.55	-1.4
NARC-IV	62	0.67	-0.88
NARC-V	62	0.64	-0.02
SWAT-84	61	1.46	0.49
WEBER	54	0.91	0.72
WILLIAM-82	60	1.09	-1.25

Mean	60
Std.error	0.26
CV	2.47

Table 14. Overall stability parameters [mean, regression coefficient (b) and deviation from regression (S^2d)] of 9 soybean cultivars, 4 locations, and 2 seasons for plant height (cm) during 1992, 1993 and 1994.

CULTIVARS	Mean	b	S^2d
CENTURY-84	70	0.98	-1.25
FS-85	71	0.98	0.16
HARPER	74	1.08	2.25
NARC-III	75	1.01	-0.90
NARC-IV	75	1.01	-0.65
NARC-V	75	1.02	0.33
SWAT-84	74	1.00	0.90
WEBER	65	0.90	-0.39
WILLIAM-82	73	1.03	-0.41

Mean	72
St.error	0.68
CV	2.36

Pod height (cm):

The pooled analysis of variance for distance of first pod from the ground is presented in Table 15. During autumn, only location showed non-significance while other sources like year, cultivar and their interaction exhibited a significant difference, demonstrating variability among cultivars and years. Analysis of variance for spring indicates significance for location and cultivar, but not for other factors. Analysis of variance for pod height on an overall basis revealed highly significant differences among the genotypes and environment, indicating the presence of variability among the cultivars as well as environment. Interactions year x location, season x cultivar, and year x season x cultivar were not significant.

The estimates of stability parameters in autumn (Table16) showed that Harper, NARC-III, NARC-IV, NARC-V, Weber, and William-82 had regression coefficients > 1. Whereas Century-84, FS-85 and Swat-84 had regression coefficients < 1. All the cultivars had very low deviations from regression demonstratin that they are very stable for pod height. The stability parameter for pod height during spring (Table 17) revealed that Harper, NARC-III and NARC-IV had means greater than the grand mean, regression coefficients about 1 and very low deviation from regression. However, Century-84 and FS-85 had means less than the grand mean with regression coefficients 0.95 and 0.98 respectively (approximately one) showing average stability to all environments. Weber had a regression coefficient < 1 and a mean also less than the grand mean.

Stability parameters simultaneously considered in overall (Table 18) analysis for individual genotypic comparison revealed the genotypes, FS-85, Harper, Swat-84, and Williams-82 had means greater than the grand mean, with regression coefficients > 1, and low deviation from regression indicating very good stability. NARC-III was greater than the grand mean with low regression coefficient (0.85) and deviation from regression (0.34). Whereas NARC-IV and NARC-V had means lower (5.4 and 5.5) respectively than grand mean with regression coefficients (0.89 and 0.83 respectively) and low deviations from regression which showed stability. Weber had a lower mean than the grand mean and regression coefficient < 1 with high deviation from regression whichshowed stability to changing environments.

Pod height is very important variable in soybean yield. It depends upon variety, growth habit, maturity and the availability of planting space. If the pod height is optimum and within the reach of the combine, the yield will be increased, but if it is too close to the ground, the yield will be reduced. If the pod height is far from the ground, the yield will also be decreased. Therefore, such cultivars should be developed which have optimum pod height so that maximum yield can be achieved.

Table 15. Analysis of variance of 9 soybean cultivars, 3 years and 4 locations for pod height (cm) of autumn, spring and overall during 1992, 1993 and 1994.

	AUTUMN		SPRING		OVERALL	
SOURCE	**DF**	**F value**	**DF**	**F value**	**DF**	**F value**
Year (Y)	2	74.7**	2	0.2NS	2	39.8**
Location (L)	1	2.2NS	2	101.7**	3	40.7**
Y x L	2	3.4**	4	0.4NS	6	1.4NS
Cultivar (C)	8	14.2**	8	3.4**	8	9.6**
Y x C	16	2.8**	16	1.3NS	16	2.3**
L x C	8	9.1**	16	0.7NS	24	3.4**
C x L x Y	16	3.2**	32	0.8NS	48	1.5*
Season (S)	-	-	-	-	1	122.8**
Y x S	-	-	-	-	2	16.7**
S x C	-	-	-	-	8	1.8NS
Y x S x C	-	-	-	-	16	1.0NS

**Significant at 0.01 probability level
* Significant at 0.05 probability level
NS Non-significant

- **Y** = Year
- **L** = Location
- **C** = Cultivar
- **S** = Season

Table16. Stability parameters [mean, regression coefficient (b) and deviation from regression (S^2d)] for pod height (cm) of 9 soybeans at 2 different locations during autumn 1992, 1993 and 1994

CULTIVARS	Mean	b	$S^2 d$
CENTURY-84	7	0.58	-0.23
FS-85	7	0.55	0.35
HARPER	8	1.53	0.42
NARC-III	7	1.42	0.75
NARC-IV	7	1.72	0.32
NARC-V	7	1.72	0.08
SWAT-84	8	0.28	0.29
WEBER	6	1.21	0.165
WILLIAM-82	8	1.03	-0.41

Mean	7
Std.error	0.09
CV	10.52

Table 17. Stability parameters [mean, regression coefficient (b) and deviation from regression (S^2d)] for pod height (cm) of 9 soybeans at 2 different locations during spring 1992, 1993 and 1994.

CULTIVARS	Mean	b	S^2d
CENTURY-84	4	0.95	-0.07
FS-85	4	0.98	0.03
HARPER	5	1.01	-0.06
NARC-III	5	1.11	-0.06
NARC-IV	4	1.12	-0.03
NARC-V	5	0.78	-0.03
SWAT-84	4	1.10	0.05
WEBER	4	0.88	0.06
WILLIAM-82	5	1.08	0.11

Mean	5
Std.error	0.06
CV	8.34

Table 18. Overall stability parameters [mean, regression coefficient (b) and deviation from regression (S^2d)] of 9 soybean cultivars, 4 locations, and 2 seasons for pod height (cm) during 1992, 1993 and 1994.

CULTIVARS	Mean	b	S^2d
CENTURY-84	5	0.89	-0.22
FS-85	6	1.17	0.01
HARPER	6	1.08	-0.22
NARC-III	6	0.85	0.34
NARC-IV	5	0.89	-0.04
NARC-V	6	0.83	0.05
SWAT-84	6	1.29	0.04
WEBER	5	0.89	0.77
WILLIAM-82	6	1.10	-0.73

Mean	6
Std.error	0.08
CV	10.34

Number of pods per plant:

The number of pods per plant is a very important component of yield. The analysis of variance for number of pods per plant for autumn, spring and overall presented in Table 19 shows that during autumn, year, location and year x cultivar interaction were not significant while year x location, cultivar, location x cultivar, and cultivar x location x year were significant. In spring, there was no significant difference in location and location x cultivar interaction while the cultivars and other interactions showed significant differences. Highly significant differences among cultivars and their interactions on an overall basis suggested that the difference among the regression coefficients (b) of the cultivars on the environment means were real, suggesting that prediction across the environment is possible (Mebrehtu et al., 1991).

The number of pods per plant during autumn (Table 20) indicates that NARC-IV had the highest number of pods per plant, a regression coefficient >1 with a low deviation from regression indicating that this genotype is sensitive to environmental fluctuations and greater specificity of adaptability to high number of pods per plant. Harper and Swat-84 had an average number of pods per plant less than the grand mean with high regression coefficients and low deviation from regression. NARC-III had the average number of pod per plant along with a low regression coefficient and deviation from regression indicating stability. During spring (Table 21), NARC-III and NARC-IV had above average means and their regression coefficients of about 1, which showed stability of these genotypes for number of pods per plant.

Table 22 shows that NARC-III, NARC-IV and NARC-V had number of pods per plant above the grand mean and regression coefficients, 1.09,1.17 and 1.05 respectively and deviation from regression 1.50, 0.84 and -0.73 respectively, indicating good stability. FS-85, Harper, Swat-84, Century-84, Weber and William-82 had mean values lower than the grand mean.

Number of pods is a very important character which effects yield, thus, it is important to select the genetic material which is stable for the development of high yield potential cultivars suitable for different ecological zones under different cropping system in Pakistan. NARC-III, NARC-IV and NARC-V were found to be stable and had a high number of pods per plant. Therefore, these cultivars should be included in the breeding program for the development of desirable soybean cultivars for commercial cultivation in different regions of Pakistan.

Table 19. Analysis of variance of 9 soybean cultivars, 3 years and 4 locations for number of pods per plant of autumn, spring and overall during 1992, 1993 and 1994.

	AUTUMN		SPRING		OVERALL	
SOURCE	**DF**	**F value**	**DF**	**F value**	**DF**	**F value**
Year (Y)	2	2.6NS	2	72.7**	2	15.0**
Location (L)	1	0.4NS	2	1.0NS	3	0.9NS
Y x L	2	17.7**	4	30.4**	6	28.2**
Cultivar (C)	8	62.6**	8	31.9**	8	73.1**
Y x C	16	1.6NS	16	1.2NS	16	1.4NS
L x C	8	3.0**	16	6.3**	24	5.7**
C x L x Y	16	1.9*	32	1.6*	48	1.7**
Season (S)	-	-	-	-	1	279.1**
Y x S	-	-	-	-	2	40.7**
S x C	-	-	-	-	8	3.1**
Y x S x C	-	-	-	-	16	1.5NS

** Significant at 0.01 probability level
* Significant at 0.05 probability level
NS Non-significant

- **Y** = Year
- **L** = Location
- **C** = Cultivar
- **S** = Season

Table 20. Stability parameters [mean, regression coefficient (b) and deviation from regression (S^2d)] of 9 soybean cultivars for number of pods per plant planted at 2 different locations during autumn 1992, 1993 and 1994.

CULTIVARS	Mean	b	S^2d
CENTURY-84	30	-0.52	-0.57
FS-85	32	0.73	1.83
HARPER	33	1.93	0.30
NARC-III	36	0.57	0.12
NARC-IV	37	1.23	-0.58
NARC-V	36	1.27	0.48
SWAT-84	33	1.48	-0.75
WEBER	28	0.07	-0.01
WILLIAM-82	32	2.23	-0.84

Mean	33
Std.error	0.23
CV	3.18

Table 21. Stability parameters [mean, regression coefficient (b) and deviation from regression (S^2d)] of 9 soybean cultivars for number of pods per plant planted at 3 different locations during spring1992, 1993 and 1994.

CULTIVARS	Mean	b	S^2d
CENTURY-84	25	0.46	0.93
FS-85	25	1.09	0.36
HARPER	27	1.22	-1.86
NARC-III	29	0.95	2.96
NARC-IV	30	0.99	2.18
NARC-V	30	1.22	-1.36
SWAT-84	27	1.08	-1.34
WEBER	25	0.58	0.26
WILLIAM-82	26	1.41	2.12

Mean	27
Std.error	0.21
Cv	6.20

Table 22. Overall stability parameters [mean, regression coefficient (b) and deviation from regression (S^2d)] of 9 soybean cultivars, 4 locations, and 2 seasons for number of pods per plant during 1992, 1993 and 1994.

CULTIVARS	Mean	b	S^2d
CENTURY-84	27	0.78	0.95
FS-85	28	1.14	0.53
HARPER	29	1.05	-0.84
NARC-III	32	1.09	1.50
NARC-IV	33	1.17	0.84
NARC-V	32	1.05	-0.73
SWAT-84	29	1.02	-1.16
WEBER	26	0.58	-0.08
WILLIAM-82	29	1.13	-2.01

Mean	30
Std.error	0.20
CV	4.98

Number of seeds per pod:

The analysis of variance for number of seeds per pod during spring, autumn and overall are presented in Table 23 shows that there is no significant difference between cultivars and their interaction with location and year. It is evident from the analysis of variance that no differential response occurred among all the genotypes for number of seeds per pod.

100-Seed Weight (g):

The analysis of variance for 100-seed weight for autumn, spring and overall presented in Table 24 shows highly significant differences among cultivars and interaction with year, location and year x cultivar. During autumn, cultivars were significantly different for 100-seed weight (g). Year x location, location x cultivar and year x location x cultivar also showed highly significant effects which demonstrated genetic differences among genotypes. This agrees with reports by Mebrahtu et al., 1991.

During spring, the analysis of variance exhibited highly significant differences for all the interactions for 100-seed weight (gm) conducted at 3 locations and 3 years. Similar results were given by Mebrehtu et al. (1991) in soybean for 100 seed weight. The overall analysis of variance for 100-seed weight (g) indicates that differences in cultivar, location and year and their interactions are highly significant.

Stability parameters during autumn (Table 25), when simultaneously considered for the individual genotype revealed that NARC-III and NARC-IV had regression coefficients > 1 and low deviations from regression. The mean performance of these varieties was higher than the grand mean indicating stability to environmental fluctuations.

The stability parameters for 100-seed weight during spring are presented in Table 26. NARC – III and NARC – IV had means greater than the grand mean with regression coefficients higher than one and low deviations from regression. NARC–V had a mean greater than the grand mean with a regression coefficient less than one and low deviation from regression.

On an overall basis for the stability parameters (Table 27) for 100-seed weight, Harper, NARC-III, NARC–IV and NARC–V showed the highest means and the greatest stability. Century–84, FS – 85, Swat – 84, Weber, Williams exhibited low 100-seed weight and low regression coefficients.

Developing cultivars with high stable 100-seed weight is a very important breeding objective. If there is any stress due to temperature or moisture, the 100-seed weight will reduce the yield of the crop. Therefore, genetic material that has high stable seed weight should be included in the breeding program. NARC-IV and NARC-V have been found to have high 100-seed weight and good stability, therefore, these cultivars should be very useful in breeding for the development of high yielding soybean for cultivation in the different cropping systems in Pakistan.

Table 23. Analysis of variance of 9 soybean cultivars, 3 years and 4 locations for number of seeds per pod of autumn, spring and overall during 1992, 1993 and 1994.

	AUTUMN		SPRING		OVERALL	
SOURCE	**DF**	**F value**	**DF**	**F value**	**DF**	**F value**
Year (Y)	2	2.29NS	2	2.06S	2	0.82NS
Location (L)	1	0.02NS	2	0.1NS	3	0.08NS
Y x L	2	1.06NS	4	0.48NS	6	0.68NS
Cultivar (C)	8	0.82NS	8	1.16NS	8	0.52NS
Y x C	16	0.93NS	16	0.86NS	16	0.61NS
L x C	8	0.94NS	16	0.58NS	24	0.70NS
C x L x Y	16	1.36NS	32	0.79NS	48	0.99NS
Season (S)	-	-	-	-	1	0.09NS
Y x S	-	-	-	-	2	3.26NS
S x C	-	-	-	-	8	0.93NS
Y x S x C	-	-	-	-	16	0.98NS

NS Non-significant

- **Y** = Year
- **L** = Location
- **C** = Cultivar
- **S** = Season

Table 24. Analysis of variance of 9 soybean cultivars, 3 years and 4 locations for 100-seed weight (g) of autumn, spring and overall during 1992, 1993 and 1994.

	AUTUMN		SPRING		OVERALL	
SOURCE	**DF**	**F value**	**DF**	**F value**	**DF**	**F value**
Year (Y)	2	0.75 NS	2	52.56**	2	20.03**
Location (L)	1	2.58 NS	2	31.56**	3	6.82**
Y x L	2	31.74**	4	34.82**	6	30.77**
Cultivar (C)	8	10.42**	8	24.78**	8	28.45**
Y x C	16	1.05NS	16	5.38**	16	2.58**
L x C	8	3.19**	16	8.43**	24	5.03**
C x L x Y	16	2.23**	32	8.43**	48	4.52**
Season (S)	-	-	-	-	1	8.52*
Y x S	-	-	-	-	2	20.50**
S x C	-	-	-	-	8	3.02**
Y x S x C	-	-	-	-	16	3.23**

** Significant at 0.01 probability level
* Significant at 0.05 probability level
NS Non-significant

- **Y** = Year
- **L** = Location
- **C** = Cultivar
- **S** = Season

Table 25. Stability parameters [mean, regression coefficient (b) and deviation from regression (S^2d)] of 9 soybean cultivars for 100-seed weight (g) planted at 2 different locations during autumn 1992, 1993 and 1994.

CULTIVARS	Mean	b	S^2d
CENTURY-84	18	1.55	-0.03
FS-85	18	0.70	0.11
HARPER	19	0.09	-0.05
NARC-III	19	1.31	-0.67
NARC-IV	19	1.12	-0.17
NARC-V	19	0.76	-0.10
SWAT-84	18	0.25	0.20
WEBER	18	1.79	0.15
WILLIAM-82	18	1.43	-.00006

Mean	18
Std.error	0.06
CV	2.25

Table 26. Stability parameters [mean, regression coefficient (b) and deviation from regression (S^2d)] of 9 soybean cultivars for 100-seed weight (g) planted at 3 different locations during spring 1992, 1993 and 1994.

CULTIVARS	Mean	b	S^2d
CENTURY-84	17	0.79	0.19
FS-85	18	1.23	-0.03
HARPER	18	0.49	0.07
NARC-III	18	1.10	-0.13
NARC-IV	18	1.14	-0.06
NARC-V	18	0.73	0.30
SWAT-84	18	1.42	-0.18
WEBER	17	0.73	0.02
WILLIAM-82	18	1.36	-0.16

Mean	18
Std.error	0.04
CV	3.09

Table 27. Overall stability parameters [mean, regression coefficient (b) and deviation from regression (S^2d)] of 9 soybean cultivars, 4 locations, and 2 seasons for 100-seed weight (g) during 1992, 1993 and 1994.

CULTIVARS	Mean	b	S^2d
CENTURY-84	18	1.22	0.08
FS-85	18	0.91	-0.001
HARPER	18	0.75	0.06
NARC-III	19	1.33	-0.13
NARC-IV	19	1.02	-0.12
NARC-V	18	0.91	0.10
SWAT-84	18	0.57	0.05
WEBER	18	1.07	0.07
WILLIAM-82	18	1.21	-0.11

Mean	18
Std.error	0.04
CV	2.79

Oil content percentage:

The pooled analysis of variance shown in Table 28 reveals a highly significant difference among cultivars and environments except in location during autumn and in season in the overall analysis, demonstrating the presence of variability among cultivars and environments. The mean values of oil percentage ranged from 20.8 to 21.3 (Table 29) during autumn. The coefficient of regression for the cultivars during autumn ranged from 0.66 to 1.32 with varying degrees of deviation from regression. The cultivars that had mean of oil content greater than the grand mean and a regression coefficient greater than one revealed stability under high oil content. Thus, Swat-84 had a mean greater than grand mean and regression coefficient > 1 showing stability for oil content.

During spring (Table 30) NARC – III and NARC- V had high oil content and regression coefficients > 1 as well as low deviations from regression. Harper and Swat-84 showed high means and regression coefficients about 1 indicating good stability. Overall (Table 31) of all genotypes, Harper, NARC-III and Swat–84 produced oil content more than the average and had regression coefficients greater than one along with low deviation from regression indicating that these genotypes were stable for oil content.

The oil percentage is a very important character for the development of soybean cultivars. The oil percentage is greatly affected by temperature during seed development (Howell and Cartter, 1953, 1958). Because of great importance of oil in Pakistan, cultivars should be developed that are stable and have high oil content. Harper, NARC-III, NARC-V and Swat-84 are stable and high in oil content, therefore, this genetic material should be used in the breeding program for the development of cultivars for commercial production.

Table 28. Analysis of variance of 9 soybean cultivars, 3 years and 4 locations for oil content (%) of autumn, spring and overall during 1992, 1993 and 1994.

	AUTUMN		SPRING		OVERALL	
SOURCE	**DF**	**F value**	**DF**	**F value**	**DF**	**F value**
Year (Y)	2	245.50**	2	63.73**	2	290.81**
Location (L)	1	2.62NS	2	15.59**	3	7.86**
Y x L	2	15.68**	4	8.74**	6	11.43**
Cultivar (C)	8	6.63**	8	10.04**	8	12.97**
Y x C	16	5.02**	16	1.93**	16	6.30**
L x C	8	2.75**	16	3.51**	24	3.08**
C x L x Y	16	3.58**	32	2.38**	48	2.82**
Season (S)	-	-	-	-	1	0.02NS
Y x S	-	-	-	-	2	24.54**
S x C	-	-	-	-	8	3.93**
Y x S x C	-	-	-	-	16	3.20**

**Significant at 0.01 probability level
NS Non-significant

- **Y** = Year
- **L** = Location
- **C** = Cultivar
- **S** = Season

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Table 29. Stability parameters [mean, regression coefficient (b) and deviation from regression (S^2d)] of 9 soybean cultivars for oil content (%) planted at 2 different locations during autumn 1992, 1993 and 1994.

CULTIVARS	Mean	b	S^2d
CENTURY-84	20.8	0.66	-0.10
FS-85	20.8	1.04	-0.03
HARPER	20.9	1.32	-0.09
NARC-III	20.9	1.20	-0.04
NARC-IV	20.9	0.96	0.22
NARC-V	20.9	0.70	-0.08
SWAT-84	21.3	1.30	0.05
WEBER	20.8	0.81	-0.09
WILLIAM-82	20.8	1.00	0.16

Mean	20.9
Std.error	0.05
CV	1.56

Table 30. Stability parameters [mean, regression coefficient (b) and deviation from regression (S^2d)] of 9 soybean cultivars for oil content (%) planted at 3 different locations during spring 1992, 1993 and 1994.

CULTIVARS	Mean	b	S^2d
CENTURY-84	20.8	0.13	0.06
FS-85	20.8	1.46	-0.00005
HARPER	21.1	0.98	-0.01
NARC-III	21.3	1.18	-0.03
NARC-IV	20.9	0.67	-0.003
NARC-V	21.0	1.38	-0.0025
SWAT-84	20.9	1.04	-0.016
WEBER	20.9	0.84	0.011
WILLIAM-82	20.9	1.32	-0.012

Mean	20.9
Std.error	0.02
CV	0.94

Table 31. Overall stability parameters [mean, regression coefficient (b) and deviation from regression (S^2d)] of 9 soybean cultivars, 4 locations, and 2 seasons for oil content (%) during 1992, 1993 and 1994.

CULTIVARS	Mean	b	S^2d
CENTURY-84	20.8	0.56	-0.02
FS-85	20.8	1.11	-0.04
HARPER	21.0	1.27	-0.04
NARC-III	21.1	1.24	-0.02
NARC-IV	20.9	0.91	0.05
NARC-V	21.0	0.84	-0.03
SWAT-84	21.1	1.19	0.05
WEBER	20.8	0.82	-0.03
WILLIAM-82	20.9	1.07	0.03

Mean	20.9
Std.error	0.02
CV	1.23

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Protein content percentage:

The analysis of variance for protein content for autumn, spring and overall basis for three years is presented in Table 32. No significant differences occurred during autumn or spring for either location or year x location. Location and season were also not significant for pooled data.

When deviation from regression was considered as a measure of stability, protein percentage remained rather stable. For individual varietal comparisons, the linear regression could simply be stated as a measure of response of particular genotypes which is reflected by a number of environments. The deviation from regression was considered as a measure of stability of the variety with the lowest or non-significant standard deviation being the most stable.

It is evident from the estimates of stability parameters (Table 31) that among all the genotypes tested in autumn, NARC-III, NARC-IV and NARC-V had high protein content and good stability. These three cultivars also had the highest protein content in the spring (Table 34). In Table 35, NARC-III, NARC-IV and NARC-V had the highest protein content overall.

Soybean protein is also of high quality. This means that soybean is "sufficiently complete to sustain life for an extended period of time." Therefore, it is very important for a developing country like Pakistan to develop cultivars which are high in quantity and quality of protein, because meat, eggs, and fish, other sources of protein, are very expensive and beyond the budget of ordinary persons. NARC-III, NARC-IV and NARC-V have high protein content and should be included in the breeding program in Pakistan.

Table 32. Analysis of variance of 9 soybean cultivars, 3 years and 4 locations for protein content (%) of autumn, spring and overall during 1992, 1993 and 1994.

	AUTUMN		SPRING		OVERALL	
SOURCE	DF	F value	DF	F value	DF	F value
Year (Y)	2	107.78**	2	128.57**	2	180.06**
Location (L)	1	5.08 NS	2	1.63 NS	3	2.86NS
Y x L	2	27.14**	4	0.68 NS	6	7.19**
Cultivar (C)	8	63.68**	8	54.55**	8	90.84**
Y x C	16	7.08**	16	7.97**	16	7.56**
L x C	8	14.38**	16	2.62**	24	5.58**
C x L x Y	16	6.97**	32	3.83**	48	4.71**
Season (S)	-	-	-	-	1	0.05 NS
Y x S	-	-	-	-	2	8.29**
S x C	-	-	-	-	8	4.84**
Y x S x C	-	-	-	-	16	3.67**

**Significant at 0.01 probability level
NS Non-significant

- **Y** = Year
- **L** = Location
- **C** = Cultivar

S = Season

Table 33. Stability parameters [mean, regression coefficient (b) and deviation from regression (S^2d)] of 9 soybean cultivars for protein content (%) planted at 2 different locations during autumn 1992, 1993 and 1994.

CULTIVARS	Mean	b	S^2d
CENTURY-84	40.2	0.51	-0.02
FS-85	40.3	1.08	-0.08
HARPER	40.5	0.81	-0.05
NARC-III	40.9	1.19	0.11
NARC-IV	40.9	1.11	0.14
NARC-V	41.0	0.62	0.01
SWAT-84	40.3	1.09	0.00
WEBER	40.2	1.25	-0.06
WILLIAM-82	40.6	1.34	-0.05

Mean	40.6
Std.error	0.34
CV	0.75

Table 34. Stability parameters [mean, regression coefficient (b) and deviation from regression (S^2d)] of 9 soybean cultivars for protein content (%) planted at 3 different locations during spring 1992, 1993 and 1994.

CULTIVARS	Mean	b	S^2d
CENTURY-84	40.2	0.06	-0.03
FS-85	40.3	1.17	0.03
HARPER	40.4	0.56	-0.01
NARC-III	40.9	1.57	0.05
NARC-IV	40.8	1.69	-0.03
NARC-V	40.9	0.89	0.11
SWAT-84	40.5	1.19	0.04
WEBER	40.1	-0.04	-0.32
WILLIAM-82	40.6	1.89	-0.03

Mean	40.5
Std.error	0.03
CV	0.54

Table 35. Overall stability parameters [mean, regression coefficient (b) and deviation from regression (S^2d)] of 9 soybean cultivars, 4 locations, and 2 seasons for protein content (%) during 1992, 1993 and 1994.

CULTIVARS	Mean	b	S^2d
CENTURY-84	40.2	0.24	-0.03
FS-85	40.3	1.13	-0.02
HARPER	40.4	0.66	-0.03
NARC-III	40.9	1.42	0.06
NARC-IV	40.9	1.46	0.03
NARC-V	40.9	0.79	0.01
SWAT-84	40.4	1.14	0.03
WEBER	40.1	0.49	-0.01
WILLIAM-82	40.6	1.67	-0.03

Mean	40.5
Std.error	0.02
CV	0.61

Yield (kg/ha):

The pooled analysis of variance (Table 36) reveals highly significant differences among cultivars and environments (location and year) and their interactions for grain yield during autumn, spring and overall. Genetic differences among genotypes for their regression on environmental index were non-significant. Diaz et al. (1990) Williams also found most cultivars stable for yield when sown in spring.

The genetic differences among cultivars for regression coefficient on the environmental index were also observed by Eberhart and Russell (1966). However, they emphasized that both the regression coefficient and deviation from regression should be considered when analyzing the phenotypic stability of a particular genotype. Samuel et al. (1970) suggested that the linearity could simply be regarded as a measure of response of a particular genotype, which depends a number of environments, whereas the deviation from regression line was considered as a measure of stability. Thus, the genotype with the lowest deviation from regression being is the most stable.

Table 37 shows that during autumn NARC-III, NARC-IV and NARC-V had high regression coefficients (1.95, 1.92 and 1.99 respectively) and means higher than the grand mean and also had low to medium deviations from regression, hence, they perform better in the high yielding environments. FS-85 and Swat-84 had regression coefficients of 1.07 and 1.29 respectively but had low yields. Harper had a yield lower than the grand mean and a low regression coefficient (0.047) and deviation from regression (-3861.61), indicating good stability in low yielding environments.

The simultaneous consideration of three stability parameters (Table 38) during spring for the individual cultivars revealed that NARC-V and NARC-IV produced high grain yield (2059 and 2049 kg/ha) and a regression coefficient around one (1.05 and 0.92) but very high deviation from regression indicating low stability. NARC-III produced a high grain yield (2049 kg/ha) and a lower regression coefficient (0.79) with low deviation from regression, indicating that this cultivar is especially good under unfavorable environments. Weber produced a grain yield (1853 kg/ha) and a regression coefficient close to one (1.10) but a high deviation from regression, indicating a high response to changes in the environments. FS-85, Harper and Swat-84 produced low grain yields and regression coefficients to above one with low deviation from regression (-2058.86, -1735.39 and – 1627.16 respectively), indicating that these cultivars may be considered good under favorable environments. The simultaneous consideration of stability parameters during overall analysis (Table 39) shows that NARC-IV and NARC-V produced higher grain yields (2248 and 2210 kg/ha respectively) and b =1.17 and 1.32 respectively, but high deviation from regression revealed that the cultivars performed better especially under favorable environments. NARC-III also had an above average grain yield and regression coefficient close to one (0.98), with a low degree of deviation from regression, indicating good stability.

Yield has a highly significant interaction with genotypes and environments. High yielding cultivars need to be developed which have wide adaptability under the different cropping systems in Pakistan. NARC-III has wide adaptability; therefore, it should be used as genetic material commercial production in Pakistan. NARC-IV and NARC-V also have high yield and good stability.

Table 36. Analysis of variance of 9 soybean cultivars, 3 years and 4 locations for yield (kg/ha) of autumn, spring and overall during 1992, 1993 and 1994.

	AUTUMN		SPRING		OVERALL	
SOURCE	**DF**	**F value**	**DF**	**F value**	**DF**	**F value**
Year (Y)	2	77.98**	2	41.18**	2	34.97**
Location (L)	1	37.71**	2	615.32**	3	457.72**
Y x L	2	18.47**	4	73.76**	6	69.41**
Cultivars (C)	8	278.85**	8	14.82**	8	107.90**
Y x C	16	15.81**	16	2.06*	16	6.33**
L x C	8	20.38**	16	3.69*	24	6.53**
C x L x Y	16	10.99**	32	2.43**	48	3.92**
Season (S)	-	-	-	-	1	60.68**
Y x S	-	-	-	-	2	212.81**
S x C	-	-	-	-	8	8.18**
Y x S x C	-	-	-	-	16	3.50**

**Significant at 0.01 probability level
*Significant at 0.05 probability level

- **Y** = Year
- **L** = Location
- **C** = Cultivars
- S = Season

Table 37. Stability parameters [mean, regression coefficient (b) and deviation from regression (S^2d)] of 9 soybean cultivars for yield (kg/ha) planted at 2 different locations during autumn 1992, 1993 and 1994.

CULTIVARS	Mean	b	S^2d
CENTURY-84	2042	-0.12	-3891.54
FS-85	2197	1.07	202.16
HARPER	2174	0.05	-3861.61
NARC-III	2461	1.95	-2982.96
NARC-IV	2563	1.92	4432.17
NARC-V	2508	1.99	-1512.49
SWAT-84	2175	1.29	4682.85
WEBER	1910	-0.06	10600.09
WILLIAM-82	2147	0.91	-7668.54
Mean	2242		
St.error	17.72		
CV	4.93		

Table 38. Stability parameters [mean, regression coefficient (b) and deviation from regression (S^2d)] of 9 soybean cultivars for yield (kg/ha) planted at 3 different locations during spring 1992, 1993 and 1994.

CULTIVARS	Mean	b	S^2d
CENTURY-84	1876	0.93	597.6
FS-85	1887	1.09	-2058.86
HARPER	1928	1.06	-1735.39
NARC-III	2049	0.79	-843.05
NARC-IV	2038	0.92	2226.22
NARC-V	2059	1.05	1549.84
SWAT-84	1945	1.12	-1627.16
WEBER	1853	1.10	1148.35
WILLIAM-82	1880	0.93	742.24

Mean	1941
Std.error	18.92
CV	3.18

Table 39. Overall stability parameters [mean, regression coefficient (b) and deviation from regression (S^2d)] of 9 soybean cultivars, 4 locations, and 2 seasons for yield (kg/ha) during 1992, 1993 and 1994.

CULTIVARS	Mean	b	S^2d
CENTURY-84	1942	0.78	-3558.82
FS-85	2011	1.06	-9154.5
HARPER	2026	0.95	-6752.21
NARC-III	2214	0.98	159.2
NARC-IV	2248	1.17	7899.2
NARC-V	2210	1.32	13906.56
SWAT-84	2037	1.02	-5487.07
WEBER	1876	0.80	13314.43
WILLIAM-82	1987	0.91	-10127.15

Mean	2061
Std.error	14.80
CV	5.78

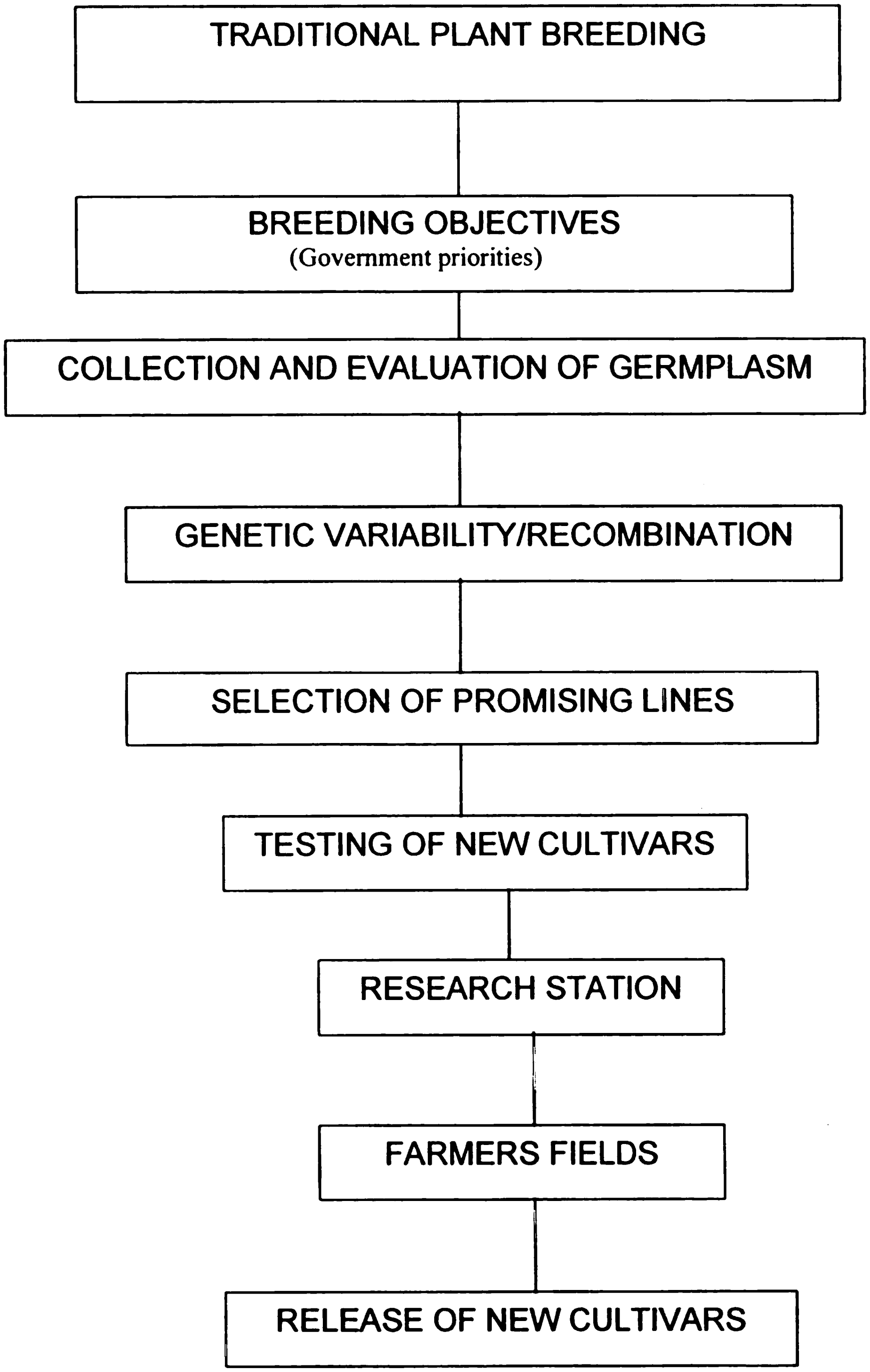
SOCIAL CHALLENGES IN PLANT BREEDING

TRADITIONAL PLANT BREEDING:

In Pakistan, all the research institutes are operated by the government, therefore, government policies are followed. According to government policies, each program has its prescribed objectives and all the experiments are formulated according to those objectives. In order to achieve the objectives, efforts are being made to collect the germplasm and evaluate it. After evaluation, crosses of desirable characters are being made to get the desirable progeny. Genetic variability is created and promising lines are selected. Due to small quantity of availability of seed, only preliminary yield trials at the research stations are conducted. Then, National Coordinated Yield Trials of the promising lines at several locations are conducted. Then, demonstration trials are conducted on the farmer's field trials. In the traditional breeding method, farmers are not involved in the selection and development of new cultivars.

A participatory plant-breeding model was developed by means of which farmers; rural leaders, processors, and consumers are involved for the development of new cultivars.

Fig. 1. Outline of traditional plant breeding program in Pakistan



PARTICIPATORY PLANT BREEDING MODEL:

In order for Pakistan to compete in global soybean production, an efficient and effective plant breeding model is needed. The new model will address the scientific, social, environmental and economic issues facing soybean production and utilization in Pakistan. The model will be developed for a public sector program, but many of the elements will also be relevant for a private sector breeding program. This model can also be used for other crops in other countries.

The new model will outline seven activities that are important for a plant breeding program including (1) determining the breeding objectives, (2) collecting genetic diversity (3) generating variability/recombination, (4) selecting new cultivars, (5) testing new cultivars, (6) disseminating the new cultivars and (7) insuring sustainable funding for the program.

Determining the breeding objectives is the first step in a seven to ten-year process of developing a new soybean cultivar. The breeder must interact with soybean farmers, consumers, processors, marketers and rural community leaders in identifying the important breeding priorities. The farmers will help to identify plant type, maturity, height, planting and harvest characteristics, biotic and abiotic stresses and other agronomic characteristics. Consumers will help to identify desirable color, taste, size, nutrition and texture traits. Marketers will identify the oil, protein and other value-added traits. The rural community leaders will help to identify environmental concerns as issues of equity and social justice. Will the cultivars be grown by the low resources farmers or high resources farmers? The rural community leaders will also look at potential value-added traits that can be bred into soybean in order to stimulate economic growth in the rural communities. Speciality oils, proteins, and carbohydrates are potential value-added traits which could bring industries to the rural community. These industries would also bring much needed jobs to the rural communities.

The next step is to prioritize the breeding objectives. Which characteristics are the most important and which will be addressed initially. Once the breeder does this, he/she must discuss prioritization of the breeding objectives with all stakeholders who helped develop the list of the breeding objectives? The breeder may need to adjust prioritization after reviewing it with the different groups. Getting feedback will be essential in developing trust with his/her clientale.

Once the breeding objectives are determined, the next step is to determine the germless that will be used in the crossing program. This will include soybean cultivars from breeding program as well as cultivars from other breeding programs in Pakistan and other countries. Wild species of soybean may also be needed for the integration of desirable characteristics. Genetic material from international gene banks will also be needed. AVRDC, IPGRI and USDA have extensive soybean collections from which to access material.

If the breeding program uses genetic engineering, then several other questions must be addressed. The first is whether the farmers will grow and /or marketers will buy the genetically modified soybean. The next is where will be got the desired genes? What promoters will be used? What terminators will be used? Do you have freedom to operate? Are there intellectual property issues that must be added? What bio-safety procedures will need to be followed?

Step three is to generate the new segregating populations. Traditional hybridization, mutagenesis or genetic engineering can be used. Some breeding programs will perform a combination of the above.

The selection process is a very complex and important step. It is important to incorporate as much science as possible to help insure success. At the same time, any process that involves multi-stakeholders in the development of new cultivars will help increase the probability of success. Screening large numbers efficiently is crucial in the development of new cultivars.

The breeder must identify the different screening procedures that will be used and will need to screen large segregating populations for resistance to insects and diseases as well other traits. Coordination with plant pathologists, entomologists, chemists and other related scientists is important. Screening for biotic and abiotic stresses can be done in the field as well as the laboratory or green house.

Farmers should be involved once some of the initial screening for the biotic and abiotic stresses is completed. Farmer selection should occur once the segregating populations have more or less stabilized (F_4 generation). Farmers can add valuable inputs into selecting material that will be entered into preliminary yield trials. There is considerable literature on ways of involving farmers in selection. Preliminary yield tests can then be tested at the experiment station. Again, farmers can be involved in rating the promising lines. However, breeders and the farmers must determine the cost and benefit of this process.

Advanced yield trials should be carried out on the experiment station as well as on several farmers' fields. Multiple locations will help to identify the stability of the important traits, i.e. yield, oil content, pest resistance etc. At least two years of advanced yield data is suggested before releasing a new cultivar.

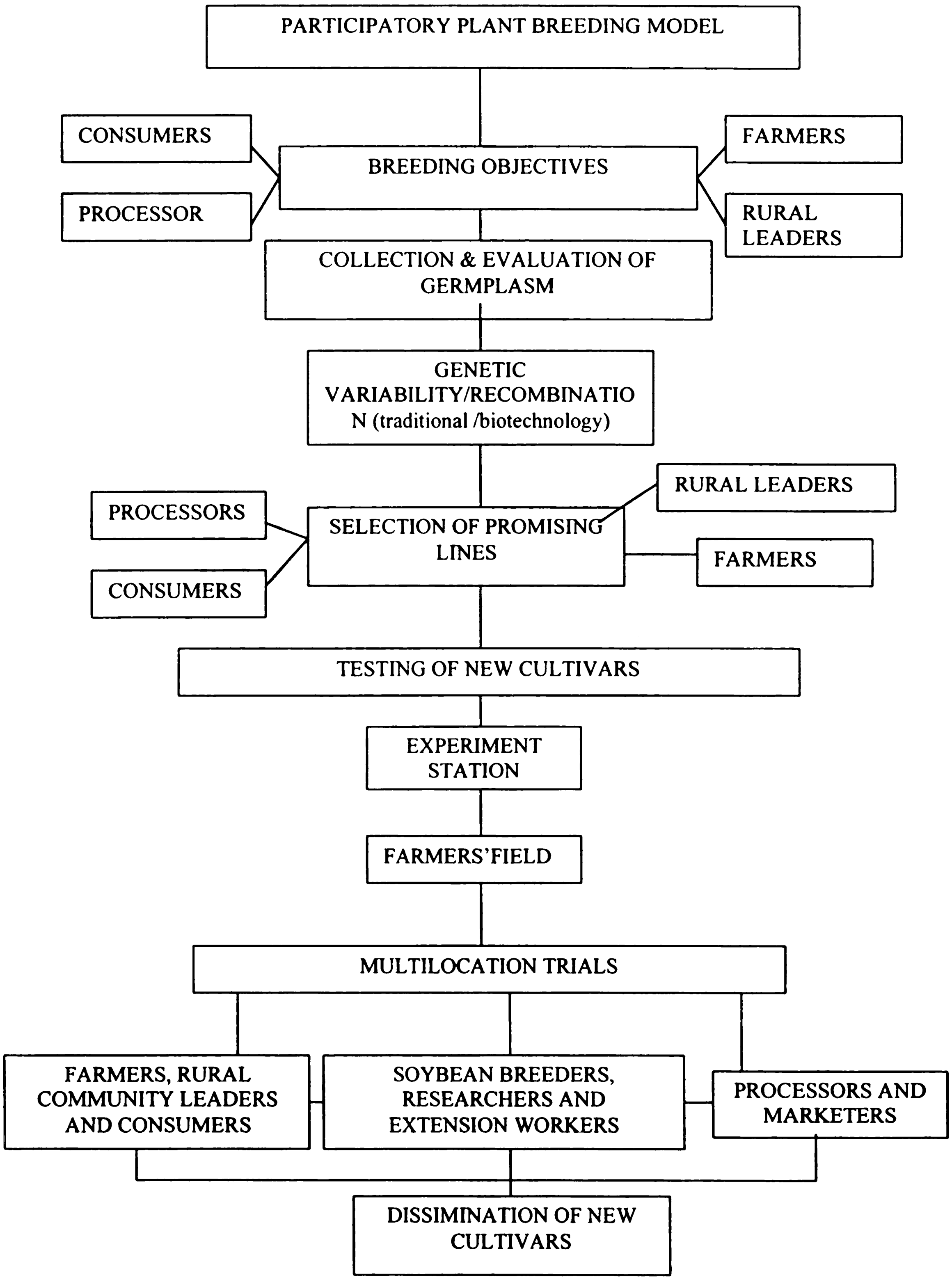
Field days are important. In this way farmers have the opportunity to visit the fields of new culitvars and also have a chance to see their performance. During the field day, dissemination of the latest production technology is also displayed and the farmers become oriented to this technology. Farmers also become aware of new cultural practices, insecticides, herbicides and other chemicals needed to achieve maximum yield.

Extension workers also need to be involved in the cultivar testing program. They can play an important role in the introduction of new soybean cultivars, especially in fallow areas by helping to disseminate production technology to farmers with the colloboration of the research workers. Also, finding ways to involve private seed companies is important. Soybean has a lot of potential and can fit in the different cropping systems under different agrological zones of Pakistan; therefore, involvement of private companies of seed will be very helpful to increase the area under soybean.

The public sector breeder should find ways to enhance the involvement of the private sector. This could be in providing enhanced germplasm for private breeding programs as well as encouraging the private sector to market cultivars. Licensing new cultivars to private companies can be very effective in getting new cultivars to the farmers.

An effective breeding program must find ways to increase the necessary funding for a successful program. Working with the farmers, industry, marketers and rural leaders will provide opportunities to get funding for the breeding program. This group will help to find funds, both public and private, for the program. In addition to the public sector funds, financial support form farmers groups, industries, foundations and seed companies are possible. Involving these people will also help keep a long-term vision for the breeding program. This group is very interested in finding new ways to participate in the global economy.

Fig. 2. Outline of Participatory Plant Breeding Model for a soybean breeding program in Pakistan.



SUMMARY

CHAPTER–V

SUMMARY

Keeping in view the significance of soybean as an oilseed crop in the country and effect of genotype x environmenr (G x E) interaction on variety performance. This present study was conducted to identify high yielding, stable genotypes along with other agronomic traits of nine genetically different genotypes of soybean (*Glycine max*). The experiments were conducted in two seasons during spring and autumn at four locations for three years 1992-94. The experiments were planted at all locations during both seasons of each year in a randomized complete block design with four replications. Plot size was four rows with 5 meters long and row spacing in autumn was 45 cm and 30 cm in spring.

Data were recorded for days to flowering, days to maturity, plant height, pod height, pods per plant, seeds per pod, 100 seed weight, oil percent, protein percent and yield. The pooled analysis of variance for days to flowering and maturity for autumn, spring and overall basis revealed significant differences among genotypes, environment and their interaction. Days to flowering and maturity were more affected by seasons as during autumn the crop took less days as compared to spring. Weber was found to be early in flowering and maturity and stable in all the environments. Therefore, Weber can be used as genetic material for the development of early varieties. Highly significant differences in pooled analysis for spring, autumn and overall basis were found for plant height. 'NARC-III', 'NARC-IV' and 'NARC-V' attained the maximum plant height during autumn and spring as well as overall. Therefore, these lines can be

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be used for the breeding program. Highly significant differences among genotypes, environment and their interaction were observed in pooled analysis of variance for spring, autumn and overall, indicating the presence of variability among the genotype as well as environment and their regression on environmental index for first mature pod height and pods per plant. During autumn, 'Swat-84' exhibited maximum pod height while 'NARC-IV' exhibited maximum pods per plant. During spring, 'NARC-III' exhibited maximum pod height where as 'NARC-V' showed the highest number of pods per plant. This genetic material can be used in the breeding program for the development of cultivars with these characteristics.

Non-significant variability was observed for number of seeds per pod. Pooled analysis of variance of 100-seed weight for spring, autumn and overall showed highly significant difference among genotypes, environment and their interaction, indicating the presence of both predictable and non-predictable components of G x E interaction. During both seasons as well as on overall, 'NARC-III', 'NARC-IV' and 'NARC-V' attained the maximum 100-seed weight and these lines can be useful for the development of cultivars having maximum grain weight.

The pooled analysis for autumn, spring and overall revealed highly significant difference among genotypes, environments and their interaction for oil and protein content percentages. Overall, Swat-84 showed the maximum oil percentage while NARC-V had the highest protein content. These lines can be useful for the development of cultivars with high oil and protein but in separate breeding programs.

There were highly significant differences among the genotypes and environments for grain yield (kg/ha) during spring, autumn seasons and overall. 'NARC-III', 'NARC-IV' and 'NARC-V' had the highest yield and showed good stability for the favorable environments.

A participatory Plant breeding model was developed which addressed the scientific, social, environmental and economic issues facing soybean production and utilization in Pakistan. The model consists of seven steps (1) determining the breeding objectives (2) collecting genetic diversity (3) generating variability/recombinations (4) selecting new cultivars (5) testing new cultivars (6) disseminating the new cultivars and (7) insuring sustainable funding for the program needed for the development of plant breeding program by means of which cultivars can be developed for different ecological zones. This model will be useful not only to increase soybean production in Pakistan but also for the development of other commodities.

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LITERATURE CITED

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APPENDIX

Table 1A. Structural changes in area of oilseed crops in Pakistan 1970-75 to 1998-99.

Year	Total oilseed area (000,ha)	Total cropped area (000,ha)	Oilseeds area (%)
1970-75	603	17.16	3.5
1975-76	562	18.02	3.1
1976-77	619	18.21	3.4
1977-78	525	18.49	2.8
1978-79	578	19.30	3.0
1979-80	534	19.22	2.8
1980-81	552	19.33	2.9
1981-82	541	19.78	2.7
1982-83	540	20.13	2.7
1983-84	463	20.06	2.3
1984-85	469	19.92	2.4
1985-86	471	20.28	2.3
1986-87	441	20.90	2.1
1987-88	400	19.52	2.1
1988-89	459	21.82	2.1
1989-90	453	21.30	2.1
1990-91	497	21.82	2.3
1991-92	496	21.72	2.3
1992-93	473	22.44	2.1
1993=94	512	21.87	2.3
1994-95	499	22.14	2.3
1995-96	569	22.59	2.5
1996-97	614	22.93	2.7
1997-98	664	23.04	2.9
1998-99	615	23.04	2.7

Source:

- Pakistan Economic Survey. 1998-99.
- Agricultural Statistics of Pakistan. 1970-91.
- FAO. STAT Database results. 1991-99 (www.FAO.Org)

Table 2A. Share of domestic production and import in the total availability of edible oil in Pakistan 1970-75 TO 1998-99.

Year	Dom.Prd . (000,t)	T. Req. (000,t)	P. C. Cm.kg/year	Import (000,t)	Import (%)
1970-75	201	307	6.5	127	38
1975-76	218	435	8.0	217	50
1976-77	228	496	9.2	268	54
1977-78	232	536	8.7	304	57
1978-79	261	602	9.0	341	57
1979-80	290	650	9.7	360	55
1980-81	271	698	10.0	427	61
1981-82	280	794	10.3	514	65
1982-83	219	870	11.1	651	75
1983-84	305	920	11.6	615	67
1984-85	349	1038	10.8	689	66
1985-86	325	1159	10.6	834	72
1986-87	462	1433	10.9	971	68
1987-88	482	1385	11.5	903	65
1988-89	478	1294	13.8	1016	79
1989-90	458	1359	12.6	901	66
1990-91	497	1449	13.0	962	66
1991-92	598	1676	13.0	1078	64
1992-93	473	1791	14.8	1318	74
1993-94	393	1846	15.3	1453	79
1994-95	450	1885	13.8	1435	76
1995-96	525	1812	15.7	1287	71
1996-97	568	1831	14.9	1263	69
1997-98	514	1844	14.0	1330	72
1998-99	532	1868	14.6	1336	72

Source:

- FAO.Food Balance Sheet 1971-99. www.FAO.Org
- Dom.Prd. Domestic Production
- Total Req. Total requirement
- P. C. Con. Per capita consumption

Table 3A. Conventional and non-conventional source of edible oil in Pakistan during 1999.

Conventional	Prod. (000, tons)	Oil (%)*	Total oil (000, tons)	Total (%)
Cottonseed	3824.00	13	497.12	71.54
Rape-Mustard	282.00	35	98.7	14.20
Goundnut	55	31	17.05	2.45
Sesame	35	44	15.4	2.22
Non-conventional				
Sunflower	195	33	64.35	9.26
Soybean**	10	19	1.9	0.27
Safflower	1.2	33	0.4	0.06

Source:

- FAO. Food Balance Sheet. 1999.

*Expeller

**Solvent extraction

Table 4A. Fatty acid composition of different vegetable oils.

Crop	Un-S. F. A. (%)		S. F. A. (%)		Other S. F. A. (%)
	Linoleic	Oleic	Stearic	Palmitic	
Safflower	78	15	2	5	1
Sunflower	68	21	5	6	11
Soybean	55	21	6	9	6
Corn	55	30	3	8	3
Cotton	51	22	2	2	1
Peanut	31	50	6	8	-
Sesame	55	21	6	9	1
Palm	8	42	5	41	-
Coconut*	2	7	2	9	-
Butter	3	35	12	27	3
Ra.& Mustard	14	18	1.5	3.5	63*

* Lauric acid 48%, other saturated acids 32%

* * Erucic acid 40%

Source:

- Thieme, J.G. (1968). Coconut oil processing. FAO, Rome
- Food. The Year Book of Agriculture. 1959, USDA.
- S. F. A. Saturated fatty acid
- Ra. & Mustard Rapeseed and Mustard

Table 5A. Existing cropping in different areas of Pakistan.

Area	Rotation		
Rice area			
	Rice	Wheat	Rice
	Rice	Fodder	Rice
	Rice	Fallow	Rice
	Rice	Matri	Rice
	(June-Nove)	(Oct-May)	(June-Nove)
Cotton Area			
	Cotton	Wheat	Cotton
	Cotton	Fallow	Cotton
	Cotton	Fodder	Cotton
	Cotton	Rapeseed and Mustard	Cotton
	(June-Dec)	(Oct-May)	(June-Dec)
Rainfed Area			
	Wheat	Fallow	Wheat/Ra.and Mustard
	(Oct-May)		(Oct-May)
	Sorghum	Fallow	Wheat
	(July-Oct)		(Oct-May)

Source:

- Wheat in the cotton-wheat farming system by Akhter, H.R., D. Byerlee, A. Qayyum, A. Majid and P.R Hobbs. 1986. P. 1-64.
- Agronomic results for wheat in rainfed area of Northern Punjab. NARC, Islamabad.

Table 6A. Proposed cropping system for soybean in different areas of Pakistan.

Area	Rotation		
Rice fallow area			
	Rice	Soybean	Rice
	(June-November)	(February-May)	(June-November)
Cotton fallow area			
	Cotton	Soybean	Cotton
	(June-December)	(February-May)	(June-December)
Rainfed area			
	Wheat	Soybean	Wheat
	(October-May)	(July-October)	(October-May)

Table 7A. Agro-meteorological data at NARC, Islamabad during 1992, 1993 and 1994.

Latitude 33° 40' N E							**Longitude 73° 10'**		
Average Temperature (°C)							**Rainfall (mm)**		
Month	**1992**		**1993**		**1994**		**1992**	**1993**	**1994**
	Max	**Min**	**Max**	**Min**	**Max**	**Min**			
January	15.4	5.5	15.2	2.9	17.1	5.0	119.1	28.3	35.1
February	17.9	5.5	21.2	7.0	17.1	6.0	83.5	46.9	47.6
March	21.7	9.2	21.1	8.3	25.6	10.8	108.7	144.7	24.8
April	27.1	13.5	29.2	14.2	28.0	12.6	46.9	27.8	70.0
May	31.9	17.2	36.4	20.3	36.0	19.5	52.5	23.6	44.0
June	37.1	22.2	37.7	23.1	40.2	23.4	23.6	83.2	69.1
July	33.4	23.9	33.1	23.7	33.1	24.1	155.6	262.5	535.1
August	32.0	24.3	33.9	23.4	31.8	23.4	182.8	224.9	578.5
September	30.4	20.5	30.6	20.5	32.1	18.1	358.4	228.8	76.6
October	28.5	13.9	29.8	12.5	28.7	11.8	12.8	0.0	44.5
November	22.9	8.3	24.8	8.7	25.2	7.6	35.0	8.7	2.2
December	19.1	6.1	21.3	3.6	17.5	4.8	8.0	0.0	126.0

Source:

- Water Resources Research Institute, NARC, Islamabad.

Table 8A. Agro-meteorological data at Fatehjang during, 1992, 1993 and 1994.

Latitude 33° 34' N							**Longitude 72° 39' E**		
Average Temperature (°C)							**Rainfall (mm)**		
Month	**1992**		**1993**		**1994**		**1992**	**1993**	**1994**
	Max	**Min**	**Max**	**Min**	**Max**	**Min**			
January	15.48	6.67	14.19	3.77	15.7	6.3	98.25	23.87	30.40
February	16.17	6.41	20.25	7.75	17.3	6.9	94.97	26.89	45.5
March	21.19	9.58	19.96	8.77	23.9	12.7	76.22	89.67	25.3
April	25.93	14.37	29.26	15.43	27.3	15.4	28.19	30.80	77.3
May	32.03	18.74	36.58	21.45	34.9	21.4	47.70	26.70	44.5
June	28.23	23.23	29.77	24.23	40.5	25.0	17.58	100.83	14.3
July	33.55	23.52	34.16	24.61	32.6	24.2	185.51	149.90	271.3
August	32.42	24.00	34.94	24.50	32.6	24.2	270.05	150.38	204.3
September	31.50	21.37	32.17	21.47	32.0	19.7	-	164.50	37.3
October	29.74	15.48	30.74	15.77	28.3	14.3	23.34	-	53.7
November	25.50	9.86	25.50	10.83	24.7	9.5	18.43	2.47	1.9
December	19.03	6.74	20.85	7.40	16.5	6.0	14.03	-	42.1

Source:

- Water Resources Research Institute, NARC, Islamabad

Table 9A. Agro-meteorological data at Gujranwala during, 1992, 1993 and 1994.

Latitude 32° 10' N							Longitude 73° 50' E		
Average Temperature (°C)							**Rainfall (mm)**		
Month	**1992**		**1993**		**1994**		**1992**	**1993**	**1994**
	Max	**Min**	**Max**	**Min**	**Max**	**Min**			
January	20.1	8.3	19.0	6.7	20.6	8.3	61.1	10.6	24.0
February	21.1	9.7	24.6	13.2	21.7	9.8	32.1	14.9	18.8
March	26.7	14.4	25.6	13.3	29.3	16.4	12.0	40.1	5.6
April	32.7	19.5	34.5	20.1	32.3	18.7	16.5	31.8	9.8
May	37.4	23.1	40.7	26.1	39.9	25.5	24.9	8.0	36.7
June	40.9	26.8	40.2	27.9	41.7	28.5	17.5	28.3	13.6
July	35.5	26.8	35.0	26.5	35.8	28.1	88.0	182.9	128.6
August	34.5	26.8	37.7	28.7	34.0	27.0	196.4	33.5	154.1
September	34.4	24.6	34.2	24.8	34.0	23.8	150.8	24.3	115.5
October	33.8	18.9	31.3	18.2	32.3	17.9	5.8	-	4.3
November	27.6	13.2	28.9	13.1	28.1	13.5	9.7	0.5	0.5
December	23.7	9.5	23.8	7.6	21.7	8.9	7.5	-	27.5

Source:

- Water Resources Research Institute, NARC, Islamabad.

Table 10A. Agro-meteorological data at Multan during, 1992, 1993 and 1994.

Latitude 30° 05' N								**Longitude 71° 40' E**	
Average Temperature (°C)							**Rainfall (mm)**		
Month	**1992**		**1993**		**1994**		**1992**	**1993**	**1994**
	Max	**Min**	**Max**	**Min**	**Max**	**Min**			
January	20.6	6.2	20.4	5.9	21.2	5.9	19.0	11.4	5.2
February	22.4	8.6	26.5	9.7	22.2	7.2	16.1	1.5	6.4
March	27.3	12.9	27.2	12.5	31.3	15.0	6.0	12.7	5.2
April	25.7	33.1	36.0	20.0	34.2	18.1	16.7	34.5	3.2
May	39.8	23.6	42.6	28.7	41.7	25.5	8.6	26.1	39.8
June	36.1	28.5	42.1	28.6	43.6	29.4	1.5	3.2	Trc.
July	38.9	28.5	36.9	27.7	37.5	28.2	15.5	209.5	51.3
August	36.1	27.4	37.6	28.0	36.7	28.2	217.3	1.8	18.6
September	34.1	24.0	37.1	28.3	34.4	23.6	201.5	Trc.	159.4
October	33.2	18.5	35.0	17.7	33.1	17.4	1.0	-	-
November	27.0	12.2	29.2	14.4	28.8	13.6	12.2	Trc.	Trc.
December	23.3	8.9	24.4	6.2	22.0	7.7	Trc.	-	15.1

Source:

- Water Resources Research Institute, NARC, Islamabad.
- Trc. Trace

Table 11A. Estimated Potential Areas for the cultivation of Oilseed Crops in Pakistan.

Land Description	**Area under different crops ('000'ha)**	**Percent (%)area readily available for oilseed crops**	**Fallow area available for Oilseeds crops ('000' ha)**
Rice	2424	30	727.2
Cotton	2923	30	876.9
Rainfed	6000	25	1500
Riverine	4500	75	337.5
Inter-cropping (sugar cane)	1155	25	288.75
Total			**3730.35**

Source:

- "Pakistan Edible Oilseeds Industry", USAID. March 1984.
- Pakistan Economic Survey. 1998-99.

Table 12A. Map of Pakistan

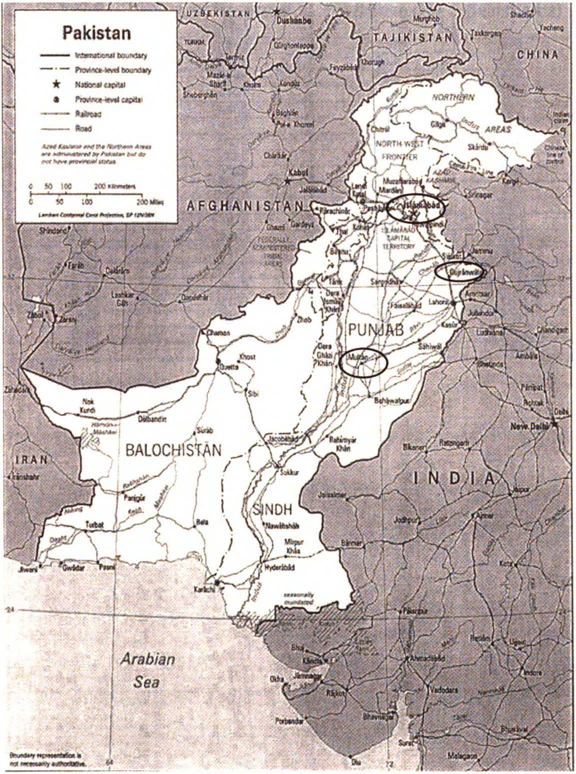

Table 13A. Area, production and yield of soybean in Pakistan 1980 – 1999.

YEAR	Area Harvested (Ha)	Production (Mt)	Yield (Kg/Ha)
1980	3512	1326	378
1981	3162	1342	424
1982	3691	1535	416
1983	4101	1350	329
1984	4465	1571	352
1985	4457	1602	359
1986	5446	2585	475
1987	5980	3775	631
1988	2758	1526	553
1989	2269	1169	515
1990	1495	849	568
1991	1875	930	496
1992	2193	1327	605
1993	4177	2355	564
1994	6613	5268	797
1995	6013	7228	1202
1996	2132	2694	1264
1997	5649	7311	1294
1998	6880	8500	1236
1999	8100	10000	1235

Source:

- FAO Database 1980-99 (www.FAO.Org)