1.0 INTRODUCTION

Common beans (*Phaseolus vulgaris L.*), originated from Central and South America and is one of the most important pulse crops in tropical Africa and tropical America. It is produced for both domestic consumption as well as for sale. In Zambia, beans are produced for the most part in Northern, North- Western and Luapula Provinces. Eastern and Central provinces also account for a sizeable portion of the overall national production. Mwale et al. (2008) stated that in many Eastern and Southern African countries, beans are a cheaper source of protein that is especially important in the diet of resource-poor people. They further observed that beans contains a higher percentage of protein as compared to staple foods such as maize, rice or cassava and that the dry grain was relatively easier to store at small scale farmer level. Most farmers grow local cultivars that are favoured for their colour and taste but have low yield potential and are susceptible to pests and diseases. Local cultivars have an average low yield of between 0.3 to 0.5 tons per hectare (MAFF Info Pack, 2000). Though improved varieties with an acceptable bean size, good colouration and taste, and with yield potential of up to 2 tons/ha as well as resistance to pests and diseases have been developed, seed is rather scarce.

Bezuneh (1992) attributed the low levels of production that have been recorded over the years to the use of local bean varieties, low soil fertility and inadequate pest control. Mwale et al. (2008) listed the challenges faced by small scale farmers in bean production as insect pests, diseases, and low yield per unit area. It was as well observed by these workers that common beans are widely susceptible to diseases such as bean mosaic virus (BCMV), angular leaf spot, common bacterial blight, anthracnose and halo blight but that amongst all these challenges, low and unstable yields were the most pertinent production problems. The gap between actual yields and potential yields is of great concern to both agronomists and plant breeders. Agronomists are constantly attempting to narrow this gap by improving production practices such as timely planting, application of adequate amounts of fertilizers, appropriate crop protection and planting of improved cultivars. The focus for plant breeders on the other hand has been towards attempting to develop high yielding beans cultivars with stable performance across an array of environments. Some improved varieties that have been released in recent years in Zambia are reflected in table 1.

Beans are grown in a wide range of environments. They are cultivated widely in the tropics, the sub-tropics and temperate regions of the world (Duke, 1983). Because of this wide cultivation, they are subjected to varying environmental conditions in terms of rainfall, soil fertility status, soil acidity and management levels. The wide variation in climatic conditions from season to season and region to region implies that no two growing conditions are similar. They may therefore perform differently depending on where they are grown. Farmers need to be availed with varieties that can perform predictably well over a wide range of environmental conditions. This would offer an opportunity for predictable yields and therefore contribute to a more stable food security situation.

Table 1: Improved Beans Varieties and Their Production Trends

Variety	Maturity (Days)	Yield Potential(Kg/Ha)	Seed Type	Characteristics
Carioca	85-95	2000	Small dull ochre	Released in 1985. High yielding; Not popular due to small dull seeds. Tolerant to fungal diseases but susceptible to BCMV
Chambeshi	85-95	1500	Large creamy	Resistant to BCMV and tolerant to most fugal diseases. Angular leaf
Lyambai	85-95	2500	Large speckled pink	High yielding, non-climber
Lukupa	85-95	2500	Large speckled creamy	High yielding, pest and disease tolerant
Solwezi Rose	85-95	2500	Plump, dull red	Very popular, high yielding, pest and disease tolerant

(Source: MAFF Info Pack 2000)

Bezuneh (1992) pointed out that given the current trends in population growth and bean consumption, demand for the crop in sub-Saharan Africa can be expected to grow at unprecedented levels well into the next century. Beans research must address this increasing demand. He stated that in most bean growing environments, land and labour scarcity severely limits the possibilities of increasing production by expanding the area planted. It was thus vital that farmers gained the means to raise bean yields per hectare on the land already cultivated. This must be without using heavy doses of purchased inputs, since most local bean growers could not afford this. Beans research must continue addressing the major challenges of depressed yield, disease and pest problems and the critical physical constraint of infertile soils and drought. Bezuneh (1992) was of the view that bean yields in sub-Saharan Africa had increased only modestly in recent years while area under production had actually declined. This worker stated that the rates of increase in bean production on this continent still lagged behind the population growth of 2.8% per year. The result was that growers were unable to meet with market demand. New bean cultivars with higher yields, multiple disease resistance and greater tolerance to drought and low soil fertility will enable farmers to increase bean productivity and achieve yield stability.

Bean production in Zambia often exhibits low yields. Some of the regularly grown varieties have small seed size with an unattractive seed coat colour. Thus they have poor marketability and low consumer preference. One of the major hindrances to increased bean production and productivity is that existing varieties on the market do not perform consistently well when grown in the different agro-ecological regions of Zambia. This limits some farmers who would be interested in growing certain common bean varieties in a particular area but are restricted by the instability of the bean yields. With the current increased research in beans and the development of new varieties of the same by institutions such as the University of Zambia, Department of Crop Science, there is a need to ensure that the yield stability of these as well as the performance in different environments are established so as to ensure that varieties being released have consistently high performance in all beans growing areas of Zambia. These varieties should be able to suit a wide array of ecological zones and should be high yielding and requiring minimal inputs.

Though stability analyses of different beans varieties in neighbouring countries such as Uganda and Malawi have been conducted before, the paucity or near absence of literature on stability research of beans varieties in Zambia is indication that not much work has been done or documented previously in establishing the yield stability of released beans varieties. This could be one of the major reasons for current low yields. It is thus imperative that proposed varieties be evaluated over a number of seasons and locations so that their environmental adaptation and performance be categorized and the variation by location be established as a precondition for their release.

The University of Zambia, Department of Crop Science has developed some beans lines using induced mutation breeding to create genetic variation. Lyambai, Solwezi Rose and Carioca varieties were used as parent material. Assessing these mutation derived lines for performance and stability will help identify much needed stable and high yielding genotypes which can contribute greatly to food security in the country. In the foregoing study it was hypothesized that the mutation derived beans lines developed by the Department of Crop Science of UNZA are superior to their parents in terms of yield and other production traits and will exhibit yield stability when grown in an array of environments. The objectives of the study were as follows:

1) To evaluate the performance in different environments of Zambia of the mutation derived lines developed by the Department of Crop Science of the University of Zambia.

2) To assess the stability of the mutation derived lines of beans developed at UNZA, when grown across an array of environments

2.0 LITERATURE REVIEW

2.1 Performance and Stability across Environments

The performance of crop cultivars can change with fluctuations in environments when there are large differences in environmental factors. A cultivar that is ideal would produce high yields irrespective of the environmental conditions in which it is grown. In actual circumstances, cultivars do not perform equally well in all environments. But the goal in plant improvement is to develop cultivars that will give good yields under varying environmental conditions. The differential response of different cultivars of the same crop species to environmental fluctuations is known as genotype x environment (GxE) interaction (Comstock and Moll, 1963). It is because of GxE interaction that testing of new lines and cultivars in areas of intended production is a standard procedure in a breeding program. From such multi-location and hence multi-environment trials, a plant breeder can establish areas of adaptation for particular genotypes and recommend for production, those cultivars that prove adapted to an environment (Comstock and Moll, 1963). Omidi (2008) stated that crop varieties are known to differ genetically for their stability across different environments. He described an ideal variety as one that combines high yield and stability of performance.

Thus GxE interactions are of major importance to the plant breeder in developing improved varieties. Information about genotype stability is useful for the selection of characteristics as well as for breeding programmes. Ali et al (2003) also found that the phenotypic performance of a genotype is not necessarily the same under diverse agro-ecological conditions. These workers observed that some genotypes may perform well in particular environments, but may yield a poor result in several others. GxE interactions play a cardinal role in the development and evaluation of plant varieties because they reduce the genotype-stability values under certain diverse environments (Herbert et al., 1995). Performance of cultivars grown over a number of environments is determined by using stability analyses (Eberhart and Russell, 1966).The concept of stability has been defined in several ways and several biometrical methods including univariate and multivariate ones have been developed to assess stability. The most widely used one is the regression method, based on regressing the mean value of each genotype on the environmental index or marginal means of environments. A good method of measuring stability was proposed by Finlay and Wilkinson (1963) and was later improved upon by Russel and Eberhart (1966).The stability of varieties was defined by high mean yield and regression coefficient (bi=1.0) and deviations from regression as small as possible ($S^2di= 0$). These workers described stability as adaptation of varieties to unpredictable and transient environmental conditions and the technique has been used to select stable genotypes that are unaffected by environmental changes.

Lin et al (1986) described 3 concepts of stability:

Type 1- a genotype is considered to be stable if its among environment variance is small.

Type2- a genotype is considered stable if its response to environments is parallel to the mean response of all genotypes in the trial.

Type3- a genotype is considered to be stable if the residual mean square from the regression model on the environmental index is small.

Type 1 describes the biological concept of stability while type 2 describes the agronomic concept of stability. Gomez et al., (1984) were of the view that in crop variety trials, the primary objective is to identify their range of adaptability. These workers also stated that a particular variety is said to be adapted to a particular site if it is among the top performers at that site. Further, the range of adaptability must include areas represented by the test sites in which the variety has shown better performance. The specific sites for the technology adaptation experiments are purposely selected to represent the geographical area or a range of environments, in which the range of adaptability of technology is to be identified. The promising lines that have shown good performance in at least one environment are usually the ones tested. At least one of the treatments tested is usually a control which represents a no- technology treatment. The results of such trials are used as the major basis for identifying the best lines as well as the range of adaptability of these. Gomez et al., (1984), further explained that technology adaptation experiments across a number of sites generally use the same set of treatments as well as the same experimental design. At the end of a crop growing season, data from the different sites are analyzed together to ascertain the treatment x site interaction effect and the average effects of the treatments over homogenous sites.

2.2 The Stability Analysis of Francis and Kannenberg

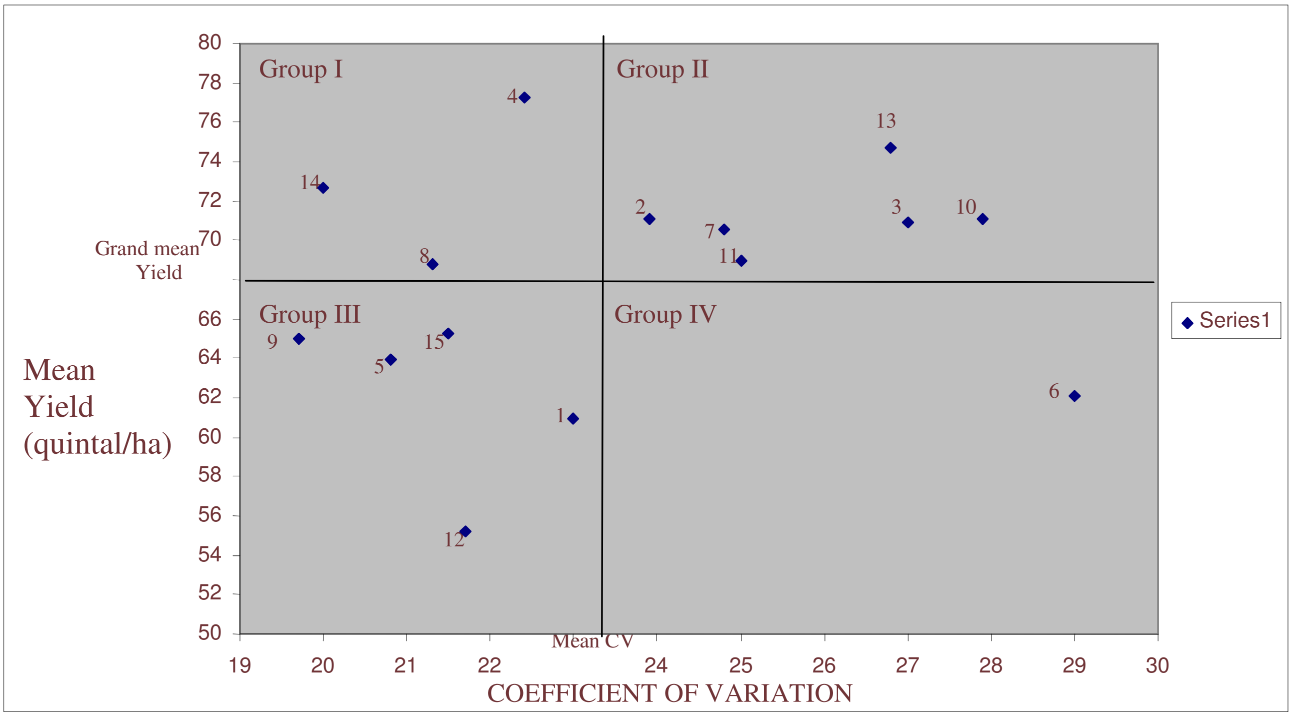
In a study on yield stability studies in short season maize, Francis and Kennenberg (1978) grew 15 single cross maize hybrids in yield tests over 16 environments. This was from 1969 to 1974. Several statistical methods for measuring yield stability were applied to the data. The study compared these techniques to the Francis and Kannenberg method and a number of problems with the other techniques were identified. Francis and Kannenberg (1978) observed that, the term stable genotype has often been used to describe a genotype that has constant performance over environments. These types of genotypes may however have below-average yields (Eberhart and Russel, 1966). If a particular line or variety for instance was found to be responsive to increased fertility, such a variety would have a greater yield variance across these levels than one that is not very responsive to varying fertility levels. The responsive one must not be looked at as unstable and would in fact be more desirable (Francis and Kannenberg 1978). The mean yield- CV method (Francis and Kannenberg method) was designed primarily to aid in studies on the physiological basis for yield stability. Francis (1977) found it more practical to characterize genotypes on a group basis rather than an individual basis. It represented a simple, descriptive method for grouping a large number of genotypes from yield data collected over several environments. In this method, mean yield was plotted against the coefficient of variation. As shown in figure 1, the mean CV and the grand mean yield divided the plotted graph into 4 groups:

Group i- high yield, small variation

Group ii-high yield, large variation

Group iii-low yield, small variation

Group iv-low yield, large variation.



(Source Francis and Kannenberg, 1978. Yield Stability Studies in Short Season Maize)

Figure 1- Mean yield plotted against CV from data collected on 15 hybrids in 16 environments

(Francis and Kannenberg- Short season maize)

Only group 1 hybrids can then be considered as stable. These provide high and consistent performance. These workers plotted the mean yield against the coefficient of variation from data collected on 15 hybrids in 16 environments (figure 1).They found that group1 hybrids appear the most stable using any approach. They described a stable genotype as one that provides high and consistent performance. By this definition only group 1 hybrids could be considered as stable. The study revealed that although group 3 was consistent, it was unstable because it performed poorly in most environments. If Finley and Wilkinson's (1963) definition of stability based on the regression co-efficient was used, group 3 would be of above average stability. Francis and Kannenberg (1978) however argued that if the deviation from regression (Eberhart and Russel, 1966) or the stability variance (Shukla, 1972) were considered, this group would be considered unstable. Other specific differences that occurred among the methods were highlighted. Some hybrids which did not appear in group1 (stable) under the Francis and Kannenberg method appeared stable using other methods. These workers observed that Hybrid 14, in group I, was deemed unstable by the stability variance and the deviation from regression. Hybrids 1, 2, and 7, not in group I, appeared stable by the other methods.

It was put forward by Freeman (1973) that the subject of GxE interaction had been worked on by statisticians, interested in non-additivity in general, quantitative geneticists and plant breeders. He further noted that quantitative geneticists are primarily interested in estimating the magnitude of the GxE interaction, while plant breeders are interested in selecting superior genotypes in the presence of GxE interaction. Francis and Kannenberg (1978) observed that the contribution of a genotype to GxE interaction does not necessarily bear any relationship to its agronomic desirability. They were of the view that in fact, genotypes that possess special adaptive characteristics such as drought tolerance may be the largest contributors to GxE interaction. Francis (1977) explained that the mean yield-cv method was designed primarily to aid in studies on the physiological basis for yield stability. It was further made clear that the method could however be used in the plant breeding context. It represented a simple, descriptive method for grouping a large number of genotypes from yield data collected over several environments.

2.3 Stability Analysis in Beans

Due to the large cultivated areas, bean plants are subjected to different environments with distinct air humidity, temperature and irradiance levels (Singh, 1989). This affects plant growth and productivity. A number of workers have conducted a number of studies on the stability of beans when grown in an array of environments using different varieties appropriate to their countries of origin. Kelly et al., (1982) investigated the yield stability of determinate and indeterminate dry bean cultivars. This was done so as to study the relationship of growth habit to yield stability. The cultivars were compared using regression of genotypic performance on environmental means. These workers looked at 28 bean cultivars differing in plant growth habit, and commercial class designation. They found that the erect, short vine, indeterminate cultivars offered the breeder the best opportunity of obtaining greater seed yield without incurring loss of yield stability as occurs with the determinate, large-seeded kidney and cranberry bean cultivars and the prostrate indeterminate cultivars. It was recommend that commercial dry bean classes should be compared separately based on center of domestication.

Gridleya and Musanab (1996) tested the multiline concept for beans in Uganda for over compensatory effects on yield and stability of yield. They demonstrated the advantages of multilines and indicated that the release of multilines was a potentially useful strategy. They found that environmental and GxE interaction effects were significant for cooking time but variation was primarily due to genotypic effect. Assefa and Gebeyehu (2003) considered the GxE interaction and stability analysis of seed yield in bean genotypes. GxE interactions, genotype response to environments and stability for seed yield of navy bean genotypes were studied. They found the linear regression model to be adequate in describing stability. Ayehal (1988) carried out a study on the yield stability in beans from diverse sources in Malawi. He found that there was a linear relationship between magnitude of diversity and stability. Svetleva (2005) found that number of pods, number of fruit branches, first pod height, seed weight, and pod length were the most useful traits for evaluating mutation derived bean breeding lines. Fageriaa and Santosa (2008) noted that the important plant traits associated with yield were root and shoot dry matter yield, pod number, 100 grain weight, leaf area index, grain harvest index, and nitrogen harvest index. They stated that these plant traits were genetically controlled and also influenced by plant and soil management practices.

2.4 Mutation Breeding

Selection was the first method of breeding aiding the criteria of suitability for man's use in terms of larger seed, better taste, easier harvesting. The ultimate source of all heritable variation to select from is mutagens. Mutation is a sudden phenotypic change in a character of an individual not due to crossing or segregation. It is a heritable change in the genetic material in an organism caused by a mutagen. Mutation breeding seeks to enhance the efficiency of induction of genetic changes. In mutation breeding, genes are altered by exposing seeds or other plant parts to chemical or physical mutagens. The relative ease of application and the comparatively low cost has caused an unexpected wave of interest in the artificial induction of mutagenesis. The usefulness of any mutagen in plant breeding depends not only on mutagenic effectiveness but also on its mutagenic efficiency (Konzak, 1964). This worker also observed that in physical mutagenesis breeding, seed is exposed to ionizing radiation of one of the three classes, namely X-rays, Gamma-rays or neurons. He described Gamma –rays as non-particulate electromagnetic radiation with a wavelength of 10^{-11} to 10^{-7} cm. These are high energy radiation and consist of photons i.e. small pockets of energy. Konzac (1964) further pointed out that gamma rays are produced by radioactive decay of certain elements e.g. ^{14}C, ^{60}Co etc. ^{60}Co is the common source of gamma-rays used for biological studies. Gamma-rays are highly penetrating and sparsely ionizing.

Through induced mutation, higher yielding and superior genotypes can be produced. This has a high potential for generating a wide range of genetic variability for breeding improved beans varieties. In induced mutation breeding, an artificial mutagen is used to create mutation. Mutation is induced by both the mechanical disruption of hereditary material in accordance with the principle of target theory and by chemical alteration of hereditary material in accordance with the direct alteration theory (Allard, 1960).

Mutation involves a change in the genetic material i.e. DNA or a heritable change in the genetic material. Mutagens may be physical or chemical. They alter the structure or sequence of DNA (Montelone, 2004). Thus genetic variation is created quicker than would be expected under natural conditions. Conventional breeding methods are thereafter employed to continue with selection once variation is achieved. Mutation breeding seeks to bring about new and improved varieties among particular agricultural crops. Mutation that is induced by radiation and other agents enhances the range of variability from which a plant breeder can select and combine different desired characteristics to come up with improved crops. Lefers (2004), points out that the important desirable characters that have been achieved include high yield, grain quality, early maturity, disease and pest resistance, improved plant type, quality characters and abiotic stress resistance. Conventional breeding which is dependent on predictable Mendelian postulates and chromosomal combination can be rather expensive, time consuming and tedious. In mutation breeding, morphological changes are achieved relatively instantaneously (Lefers, 2004).

The rate of mutation varies with the dose of the mutagen. A higher mutagen dose results in more frequent mutations as well as a greater associated possibility of damage and lethality. An acceptable dose is that at which 50% of the treated material is killed. This is referred to as 50% lethal dose or LD50 (Lefers, 2004). Induced mutation creates variation in self pollinated plants which have limited genetic variation due to limited gene recombination (Lacandula, 2004). Mutation induction rarely produces new alleles. It produces alleles which are already known to occur spontaneously or may be discovered if an extensive search were made. Mutations occur in nature at a low rate. These are referred to as spontaneous mutations. However, induced mutations occur at a much higher frequency than spontaneous mutations implying that it is more practical to work with them. Singh (1983) summarizes the various applications of mutation breeding as:

1. Inducing desirable mutant alleles which may not be present in the germplasm or which may be present, but may not be available to the breeder due to political or geographical reasons.

2. It is useful in improving specific characteristics of a well adapted high yielding variety.
3. Used to improve various quantitative characters including yield. Several varieties have been developed using the technique.
4. F1 hybrids from intervarietal crosses may be treated with mutagens in order to increase genetic variability by inducing mutations and by facilitating recombination among linked genes.
5. Irradiation of inter-specific (distant) hybrids has been done to produce translocations. This is done to transfer a chromosome segment carrying a desirable gene from the alien chromosome to the chromosome of a cultivated species.

2.5 Work in Beans Improvement

Research on grain legumes in Zambia dates back to the sixties and this was under the Agricultural Research branch. A number of legume crops were initially worked on and these included groundnuts (*Arachis hypogeae L.*), common beans (*Phaseolus vulgaris L.*), cowpeas (*Vigna unguiculata*), and Bambara groundnuts (*Vigna subterranean*). By 1980, the scarcity of financial support meant that research on legumes was narrowed down to field beans, cowpeas, ground nuts and bambara nuts. Other legumes such as winged beans and mungbeans were only grown as collection or rejuvenation plots. Research on legume crops in the late sixties through to the seventies, did not produce technological packages appropriate to small holder or traditional farmers (Mulila and Javaheri, 1994). Intensive research work was conducted in 1982 for beans with assistance from IBRD/IFAD. From 1988 to date, the Food Legumes Research Team has a national mandate for research into improved productivity and production of food legume crops.

The University of Zambia, Department of Crop Science started work on character improvement of *Phaseolus vulgaris* in the 2000/01 growing season for Carioca variety. In 2003/04 season this work was extended to Lyambai, Lukupa and Solwezi Rose varieties. The work had the main objective of improving the bean crop with respect to selection for improved yields and for traits that enhance preference. Induced mutation breeding method was used to create genetic variation in common beans. Seeds of the same were irradiated with Gamma radiation at 150 Grays at the Gamma radiation source facility of the National Institute for Scientific and Industrial Research in Lusaka, Zambia. The pedigree method of breeding was followed. Selection was carried out within family (single plant basis) and between families.

Carioca bean variety was evaluated by the Department of Crop Science of UNZA from M1 to M6 based on improvements in yield components, seed coat colour, maturity and tolerance to pests and diseases. In 2004/2005 growing season 27 mutants of Carioca variety were evaluated for their nitrogen fixing capacity and nitrogen assimilate partitioning with respect to parent. The Carioca mutants were also evaluated for their mineral composition especially with respect to iron, zinc and selenium. Significant differences were observed in nitrogen fixing capacity and assimilate partitioning among the mutants and the parent. It was found that all the mutants apart from CA15-40-4-B and CA23-4-2-B fixed more nitrogen than the parent, (Legume Improvement Preliminary Report, 2006). In February 2006, selected mutants were evaluated for performance in different environments with respect to yields, maturity, morphological traits, seed coat colour and seed size, nutritional composition and tolerance to pests and diseases. CA18-22-B1 was about 5 days later in maturity than the parent. Other mutants such as CA15-4-4-B1 showed a seed size that was 6% more than the parent. (Legume Improvement Preliminary Report, 2006). Lyambai, Solwezi Rose and Lukupa bean varieties were evaluated from M1 to M5. It was found that there were significant differences in maturity, pod and seed yield, pod and seed coat colour and seed size with respect to the parent, (Legume Improvement Preliminary Report, 2006).

3.0 MATERIALS AND METHODS

Twenty two mutation derived beans lines plus 3 parent lines were evaluated for their performance as well as assessed for their yield stability in different environments by setting up experimental plots in three different locations. These were Chafukuma Farmer Training Institute in Solwezi, Misamfu Research station in Kasama and Golden Valley Agricultural Research Trust in Chisamba. The 22 mutation derived lines plus their 3 parent lines where assigned treatment numbers and line designations as shown in Table 2. The mutation derived lines were developed at the University of Zambia, Department of Crop Science under an on-going programme to come up with improved beans varieties. The lines were in their M7 generation. The Golden Valley trials were planted on January 10, 2009, the Solwezi trials were planted on February 29, 2009 while the Kasama trials were planted on January 15, 2009. A spacing of 60cm x 15cm was used in each of the three experiments. D-compound fertilizer was used as a basal dressing. This contains nitrogen, phosphorus and potassium in the ratio 10:20:10. Fertilizer application in each of the three experimental areas was at the rate of 200 kg/ha of D-compound fertilizer at the time of planting. The experimental areas were all weeded twice. Relevant parameters were measured as the crop developed as well as at harvest time. These parameters were as follows:

i. Days to 50% flowering (D50%F): this was taken as the number of days from planting to when 50% of the plants in the plot were in bloom;
ii. Days to physiological maturity (DTM): this was collected when 50% of the plants had reached this stage;
iii. Pod length –mm (PLGTH): this was taken as the length of the pods from the base to the tip of 100 randomly selected pods;
iv. Grain yield per hectare-kg/ha (y/ha): this data was collected at harvest time;
v. 100 seed weight (g) (HSW): this was determined by physically counting 100 seeds at random and weighing.

Table 3 shows the areas in which the lines were planted, the corresponding agro-ecological regions and rainfall range.

Table 2: Treatment Number to Beans Lines Designation

TREATMENT NO.	BEANS LINES
T1	LY2-7-8
T2	LY2-8-B
T3	LY4-4-B
T4	LY1-2-B
T5	LY2-3-B
T6	LY2-6-B
T7	LY1-7-B
T8	LY-PARENT
T9	SZ3-1-B-B
T10	SZ9-7-B-B
T11	SZ3-2-B-B_1
T12	SZ9-B-B-B_1
T13	SZ7-4-B-B
T14	SZ9-B-B-B_2
T15	SZ3
T16	SZ-PARENT
T17	CA-PARENT
T18	CA15
T19	CA18
T20	CA38
T21	CA3
T22	CA9
T23	CA24
T24	SZ3-3-B-B_2
T25	LY2-2-B

Table 3: Trial Locations and their Corresponding Agro-ecological Zones

LOCATION	AGRO-ECOLOGICAL ZONE	RAINFALL RANGE (mm)
Golden Valley (Chisamba)	Region II	800-1000
Chafukuma Institute (Solwezi)	Region III	> 1000
Misamfu Research Station (Kasama)	Region III	>1000

3.1 Experimental Design

The balanced lattice design was the preferred experimental design for this study. This is because the study involved a single factor with a relatively large number of treatments. This is an incomplete block design in which each block does not contain all the treatments and a reasonably small block size can be maintained. In this way, the homogeneity of experimental units in the same blocks was easier to maintain and a higher degree of precision was to be generally expected. A 5x5 lattice design was used consisting of 22 mutant lines and 3 parent lines. Therefore, the total number of treatments was 25. The number of replications (r) was 6 while the block size (k) was 5. The field layout was as indicated in appendix 7. Each replication covered an area of 9m x 20m. The total experimental area was 1245m² (30m x 41.5m). Each plot had two planting rows. This was due to a limitation on planting material. Each row and hence each plot was 4m in length. Each plot within a replication had an area of 1.8m x 4m. The space between the replications was 1.5m. A spacing of 60cm x 15cm was used for each beans lines in a plot. The seed requirement per line was 52.

3.2 Data Analysis

The data was analysed using Genstat discovery edition 3. This included analysis of variance and mean comparison by least significant diference . The stability analysis of Francis and Kannennberg (1978) was used to determine the genotypes that were stable across all the environments and therefore superior. The mean yield of each mutation derived beans line was plotted against their corresponding co-efficient of variation percentage (CV %). The co-efficients of variation were plotted along the x-axis while the mean yields were plotted along the y-axis. These were plotted as a scatter diagram.
The mean CV and the grand mean yield were used to divide the scatter diagram into 4 groups as per procedure of the Francis and Kannenberg method described in the literature review (section 2.2).

4.0 RESULTS

4.1 Weather

The weather data at all three sites is reflected in appendix 6. Rainfall at all three sites was for the most part consistent with the rainfall patterns for the respective agro-ecological zones at which the sites were set up although GART experienced some reduced rainfall in the month of February when only 60mm of rainfall was recorded for that month. The dry period experienced at GART was a source of concern. Supplementary water supply by way of irrigation was almost introduced but the rainfall situation normalized before this became necessary. Chafukuma (Solwezi) also experienced below average rainfall in the months of April and May 2009. 40.4mm and 35mm were recorded respectively. This was however nearing the harvest period. There was not much effect however on the plants as late planted beans in that region rely mostly on residual moisture. During the period between January and April 2009 in which the beans lines were grown at all the three sites, maximum temperatures ranged between 24°c and 29°c which was within the expected average for these regions.

4.2 Analysis of Variance and Treatment Means

The summary of the results of the analysis of variance and the mean squares for each of the characters studied are shown in Table 4. The detailed analyses of variance for each of the characters are reflected in appendices 1 to 5 in the appendix section. Tables 5 to 9 show the treatment means in terms of how each of the lines performed at each of the three locations as well as the combined means and the mean difference obtained as the difference of the mean of each line with that of each respective parent. The results are elaborated below.

Table 4: Summary of ANOVA Tables

	DF	Y/HA MS	D50%F MS	DTM MS	HSW MS	PL MS
Site	2	221722**	5.016**	7.796^{ns}	12613.88***	379.2**
Line	24	107433***	20.449***	58.842***	1041.55***	1052.8***
Site x Line	48	90461***	1.958^{ns}	7.555^{ns}	181.78***	99.7^{ns}
LSD		242.2	1.427	3.149	11.251	13.638
CV%		11.9	3.5	4	22.6	10.6
Mean		1794	35.82	69.8	43.94	113.79

*** Highly significant
** Very significant
* Significant
ns Not significant

4.2.1 Yield per Hectare

The results of the variance analysis (Table 4) showed that the treatment means for the sites were significantly different from each other ($p \leq 0.05$).The treatment means for the lines were also significantly different ($p \leq 0.01$). The effect of the site by line interaction was as well highly significant.

The treatment means, and the mean differences for y/ha in the lines under study are shown in Table 5. None of the mutation derived lines had higher yields than their respective parents. The yields of all the lines under study were not significantly different from their parents. On the whole, SZ mutant lines had higher yields than both CA and LY mutant lines. Yields were highest at GART followed by Chafukuma and then Misamfu with respective site means being 1837 kg/ha, 1784 kg/ha and 1762 kg/ha. These were significantly different ($P \leq 0.01$). The highest yield for CA lines was at GART (1814 kg/ha) while the lowest was in Kasama (1730 kg/ha). The highest yield for LY lines was at GART (1869 kg/ha) while the lowest was in Chafukuma (1751 kg/ha). The SZ lines had their highest yield in Chafukuma (1814 kg/ha) and their lowest yield in Misamfu (1789 kg/ha)

Table 5: YIELD PER HECTARE TREATMENT MEANS (kg/ha)

	GART	KASAMA	SOLWEZI	COMBINED	MEAN DIFF
CA-PRNT	1569	1667	1872	1703	
CA15	1896	1813	1913	1874	171
CA18	1712	1819	1875	1802	99
CA24	1906	1684	1910	1833	130
CA3	1944	1639	1917	1833	130
CA38	1788	1646	1111	1515	-188
CA9	1882	1844	1778	1834	131
Site mean	1814	1730	1768	1771	
LY-PRNT	1667	1830	1708	1735	
LY1-2-B	1938	1757	1722	1806	71
LY1-7-B	1806	1726	1812	1781	46
LY2-2-B	1674	1674	1861	1736	1
LY2-3-B	1997	1785	1667	1816	81
LY2-6-B	1938	1743	1646	1775	40
LY2-7-B	1983	1847	1799	1876	141
LY2-8-B	1920	1771	1819	1837	102
LY4-4-B	1896	1701	1729	1775	40
Site mean	1869	1759	1751	1793	
SZ-PRNT	1531	1736	1837	1701	
SZ3	1698	1826	1920	1815	114
SZ3-1-B-B	1906	1861	1924	1897	196
SZ3-2-B-B1	1941	1760	1771	1824	123
SZ3-3-B-B2	1997	1677	1837	1837	136
SZ7-4-B-B	1816	1816	1753	1795	94
SZ9-7-B-B	1920	1837	1819	1859	158
SZ9-B-B-B1	1865	1816	1819	1833	132
SZ9-B-B-B2	1733	1774	1785	1764	63
Site mean	1823	1789	1829	1814	
Site mean	1837	1762	1784	1794	
LSD 0.05				242.2	
CV%				11.9	

4.2.2 Days to 50% Flowering

From the summary ANOVA (Table 4) it can be seen that the effect of the site was found to be significant ($p \leq 0.05$). This is to say, the lines performed differently depending on which site they were grown at. The effect of the line was highly significant. The site x line interaction however was not significant. The effect of one did not depend on the other. As shown in Table 6, among the CA lines, CA38 and CA 9 flowered earlier than their parent by an average of 2 days. This was significant at 5% probability level. Among the LY lines, only LY2-2-B and LY2-7-B flowered earlier than their parent by an average of 2.5 days. This was significant at a probability level of 5%. The rest of the LY lines had similar D50%F as their parent. Among the SZ lines, SZ3-1-B-B and SZ3-3-B-B2 flowered earlier than their parent ($p \leq 0.05$). This was by an average of 1.8 days.

4.2.3 Days to Maturity

As can be seen in the summary ANOVA (Table 4), the effect of the site was not significant. The effect of the line was however highly significant. The site x line interaction was also not significant. All the CA lines matured earlier than their parent ($p \leq 0.05$) (Table 7). They matured earlier by an average of 6 days. All the LY and SZ mutant lines had similar days to maturity as their respective parents. This was the case at all three sites.

Table 6: DAYS TO 50% FLOWERING- TREATMENT MEANS

	GART	KASAMA	SOLWEZI	COMBINED	MEAN DIFF
CA-PARENT	37	38.5	36.667	37.389	
CA15	37.167	37.5	36.5	37.056	-0.333
CA18	37.833	37.667	36.5	37.333	-0.056
CA24	35	34.667	33.5	34.389	-3
CA3	36.5	37.167	36.167	36.611	-0.778
CA38	34.833	36	35.5	35.444	-1.945
CA9	35.667	35.333	36.167	35.722	-1.667
Site mean	36.286	36.691	35.857	36.278	
LY-PARENT	37.167	36	36	36.389	
LY1-2-B	35.167	36	35.833	35.667	-0.722
LY1-7-B	36.167	35	36.5	35.889	-0.5
LY2-2-B	34	33.333	33.667	33.667	-2.722
LY2-3-B	36.833	36	37.333	36.722	0.333
LY2-6-B	37	38	36.833	37.278	0.889
LY2-7-B	34	33.667	34.167	33.944	-2.445
LY2-8-B	35	36.333	35.833	35.722	-0.667
LY4-4-B	36	36.833	36.5	36.444	0.055
Site mean	35.704	36.685	35.82	35.747	
SZ-PARENT	35.667	36.667	36.167	36.167	
SZ3	36	36.833	37.333	36.722	0.555
SZ3-1-B-B	34.167	35	34.333	34.5	-1.667
SZ3-2-B-B1	35	35.333	35.5	35.278	-0.889
SZ3-3-B-B2	34.333	34	34.333	34.222	-1.945
SZ7-4-B-B	34.333	35.667	35.167	35.056	-1.111
SZ9-7-B-B	36.333	36	35.167	35.833	-0.334
SZ9-B-B-B1	36	36.167	35.333	35.833	-0.334
SZ9-B-B-B2	35.833	37.167	35.833	36.27	0.103
Site mean	35.296	35.870	35.463	35.542	
Site mean	35.72	36.03	35.713	35.822	
LSD 0.05				1.427	
CV%				3.5	

Table 7: DAYS TO MATURITY TREATMENT MEANS

	GART	KASAMA	SOLWEZI	COMBINED	MEAN DIFF
CA-PARENT	76	75.33	73	74.78	
CA15	71.67	68.5	70.5	70.22	-4.56
CA18	67.33	67	68.17	67.5	-7.28
CA24	67.5	68	69.83	68.44	-6.34
CA3	64.33	65.67	68.67	66.22	-8.56
CA38	69.17	71.5	70	70.22	-4.56
CA9	69.17	69	69.83	69.33	-5.45
Site mean	69.31	69.29	70	69.53	
LY-PARENT	70.17	69.33	71.83	70.44	
LY1-2-B	71.33	70.83	70.83	71	0.56
LY1-7-B	68.33	69.33	69.17	68.94	-1.5
LY2-2-B	70.5	70.17	70.67	70.44	0
LY2-3-B	70.17	70.17	71.17	70.5	0.06
LY2-6-B	70.33	70	69.33	69.89	-0.55
LY2-7-B	71.17	70.17	71	70.78	0.34
LY2-8-B	71.67	69.67	70.17	70.5	0.06
LY4-4-B	71.33	69.67	70.5	70.5	0.06
Site mean	70.56	69.93	70.52	70.33	
SZ-PARENT	69.67	69.67	70.17	69.83	
SZ3	68.17	68.17	70.17	68.83	-1
SZ3-1-B-B	66.5	67	68.33	67.28	-2.55
SZ3-2-B-B1	66.83	68.17	69.67	68.22	-1.61
SZ3-3-B-B2	67.17	70	68.67	68.61	-1.22
SZ7-4-B-B	65.67	68.17	68.33	67.39	-2.44
SZ9-7-B-B	73.33	71.17	70.17	71.56	1.73
SZ9-B-B-B1	72.5	72.83	70.33	71.89	2.06
SZ9-B-B-B2	72.17	71.67	71	71.61	1.78
Site mean	69.11	69.65	69.65	69.47	
Site mean	69.69	69.65	70.06	69.8	
LSD 0.05				3.149	
CV%				4	

4.2.4 HUNDRED SEED WEIGHT

The Analysis of Variance for hundred seed weight (Table 4) revealed that there were highly significant differences ($p \leq 0.01$) for HSW in terms of the effect of the site as well as for the effect of the line. This was the case also for the site x line interaction. The treatment means for hundred seed weight are given in Table 8. None of the mutation derived lines had a higher HSW than their respective parents. In the CA lines HSW was highest at GART (37.62g) and lowest an Chafukuma (38.5g). The trend was similar for SZ mutant lines. The highest score for these was at GART (60g) while the lowest was at Chafukuma (43.57g).

4.2.5 POD LENGTH

The analysis of variance results (Table 4) showed that the effect of the site was found to be significant ($p \leq 0.05$).The effect of the line was highly significant while the site x line interaction was not significant. The effect of the site did not depend on the line and vice versa. Only SZ3-3-B-B2 was significantly higher than its parent at a probability level of 5 percent. (Table 9) The rest of the mutant lines had similar pod length with their parents. Pod length was generally highest in Misamfu and lowest at GART.

Table 8: HUNDRED SEED WEIGHT TREATMENT MEANS (g)

	GART	KASAMA	SOLWEZI	COMBINED	MEAN DIFF
CA-PARENT	41.67	41.67	31.67	38.33	
CA15	43.33	30	25	32.78	-5.55
CA18	33.33	36.67	25	31.67	-6.66
CA24	41.67	36.67	26.67	35	-3.33
CA3	36.67	40	23.33	33.33	-5
CA38	35	36.67	20	30.56	-7.77
CA9	31.67	30	23.33	28.33	-10
Site mean	37.62	35.95	25	32.86	
LY-PARENT	65	41.67	39.83	48.83	
LY1-2-B	60	40	38.33	46.11	-2.72
LY1-7-B	63.33	38.33	43.33	48.33	-0.5
LY2-2-B	60	41.67	28.33	43.33	-5.5
LY2-3-B	55	40	38.33	44.44	-4.39
LY2-6-B	63.33	46.67	40	50	1.17
LY2-7-B	65	41.67	40	48.89	0.06
LY2-8-B	56.67	40	40	45.56	-3.27
LY4-4-B	63.33	45	38.33	48.89	0.06
Site mean	61.3	41.67	38.5	47.15	
SZ-PARENT	66.67	45	48.33	53.33	
SZ3	60	40	43.33	47.78	-5.55
SZ3-1-B-B	61.67	43.33	42.17	49.06	-4.27
SZ3-2-B-B1	60	48.33	43.33	50.56	-2.77
SZ3-3-B-B2	66.67	48.33	46.67	53.89	0.56
SZ7-4-B-B	63.33	48.33	33.33	48.33	-5
SZ9-7-B-B	58.33	43.33	38.33	46.67	-6.66
SZ9-B-B-B1	53.33	36.67	45	45	-8.33
SZ9-B-B-B2	50	46.67	51.67	49.44	-3.89
Site mean	60	44.44	43.57	49.34	
Mean	54.2	41.07	36.55	43.94	
LSD 0.05				11.251	
CV%				22.6	

Table 9: POD LENGTH TREATMENT MEANS (mm)

	GART	KASAMA	SOLWEZI	COMBINED	MEAN DIFF
CA-PARENT	96	107	103.5	102.17	
CA15	96	105.5	102.33	101.28	-0.89
CA18	105.33	115.5	107.67	109.5	7.33
CA24	104.17	114.33	110.33	109.61	7.44
CA3	104.5	113.33	110.5	109.44	7.27
CA38	99.33	115.33	107.33	107.33	5.16
CA9	104	109	108.33	107.11	4.94
Site mean	101.33	111.43	107.14	106.63	
LY-PARENT	112.83	113.5	117.5	114.61	
LY1-2-B	127.17	126.67	122	125.28	10.67
LY1-7-B	120.33	124.83	123.5	122.89	8.28
LY2-2-B	101.83	109.33	110.5	107.22	-7.39
LY2-3-B	116.5	123.33	119.83	119.89	5.28
LY2-6-B	127	123.5	126.33	125.61	11
LY2-7-B	125.67	119.33	125.5	123.5	8.89
LY2-8-B	117.67	115	119.17	117.28	2.67
LY4-4-B	109.33	112.5	114.17	112	-2.61
Site mean	117.59	118.67	119.83	118.7	
SZ-PARENT	110.67	113	112	111.89	
SZ3	121.33	121.17	120.5	121	9.11
SZ3-1-B-B	113.5	115.5	116	115	3.11
SZ3-2-B-B1	108.5	110.17	109.33	109.33	-2.56
SZ3-3-B-B2	128	124.67	124.83	125.83	13.94
SZ7-4-B-B	103.17	110.83	103.33	105.78	-6.11
SZ9-7-B-B	105.67	108.17	110.67	108.17	-3.72
SZ9-B-B-B1	134.5	111	124.5	123.33	11.44
SZ9-B-B-B2	106.67	112.33	110	109.67	-2.22
Site mean	114.67	114.09	114.57	114.44	
Mean	111.99	114.99	114.39	113.79	
LSD 0.05				13.638	
CV%				10.6	

4.3 STABILITY ANALYSIS

This was done in order to identify superior genotypes in the presence of GxE interaction. The statistical method used to assess stability across environments was that proposed by Francis and Kannenberg (1978). Table 10 shows the mean yields and co-efficients of variation for each respective beans lines and the 3 parent varieties. The error mean square as obtained from the ANOVA for yield per hectare in appendix 1 was 45528. The CV percentage for each line was obtained by getting the square root of the error mean square and then dividing the result by the individual genotype mean yield. This was then multiplied by 100. The mean yields were plotted against the coefficients of variation in a scatter diagram. The beans lines were then divided into four groups using the overall mean of the yield and the overall mean of the CVs. The overall mean of the CV percentages was 11.9 while the overall mean for the yield per hectare was 1794 kg/ha as obtained from Table 5 which gives the yield per hectare treatment means. The scatter diagram that was subsequently obtained is shown in Figure 2. Because some of the lines had similar average yields, some of the lines fell on the same points. Thus the scatter diagram produced only 16 points. Thus points a to q represent all the 25 genotypes that were under study. The key accompanying Figure.2 shows the genotypes that were contained at each point. It was found that the following lines were stable: CA15, CA18, CA24, CA3, CA9, LY1-2-B, LY2-3-B, LY2-7-B, LY2-8-B, SZ3-1-B-B, SZ9-7-B-B, SZ3-2-B-B1, SZ9-B-B-B1, SZ7-4-B-B, SZ3, SZ3-3-B-B2. This represented group I. The unstable lines were: SZ-PARENT, CA- PARENT, LY-PARENT, CA38, LY1-7-B, LY2-2-B, LY2-6-B, LY4-4-B AND SZ9-B-B-B2. This represented group IV. There were no lines falling in group II and group III. These results are summarized in Table 11.

Table 10: CV% and Mean yield of the Beans Lines

Bean lines	cv%	y/ha
CA-PARENT	12.53	1703
CA15	11.39	1874
CA18	11.84	1802
CA24	11.64	1833
CA3	11.64	1833
CA38	14.08	1515
CA9	11.63	1834
LY-PARENT	12.29	1735
LY1-2-B	11.81	1806
LY1-7-B	11.98	1781
LY2-2-B	12.29	1736
LY2-3-B	11.74	1816
LY2-6-B	12.02	1775
LY2-7-B	11.37	1876
LY2-8-B	11.61	1837
LY4-4-B	12.02	1775
SZ-PARENT	12.54	1701
SZ3	11.75	1815
SZ3-1-B-B	11.25	1897
SZ3-2-B-B1	11.70	1824
SZ3-3-B-B2	11.62	1837
SZ7-4-B-B	11.89	1795
SZ9-7-B-B	11.48	1859
SZ9-B-B-B1	11.64	1833
SZ9-B-B-B2	12.09	1764

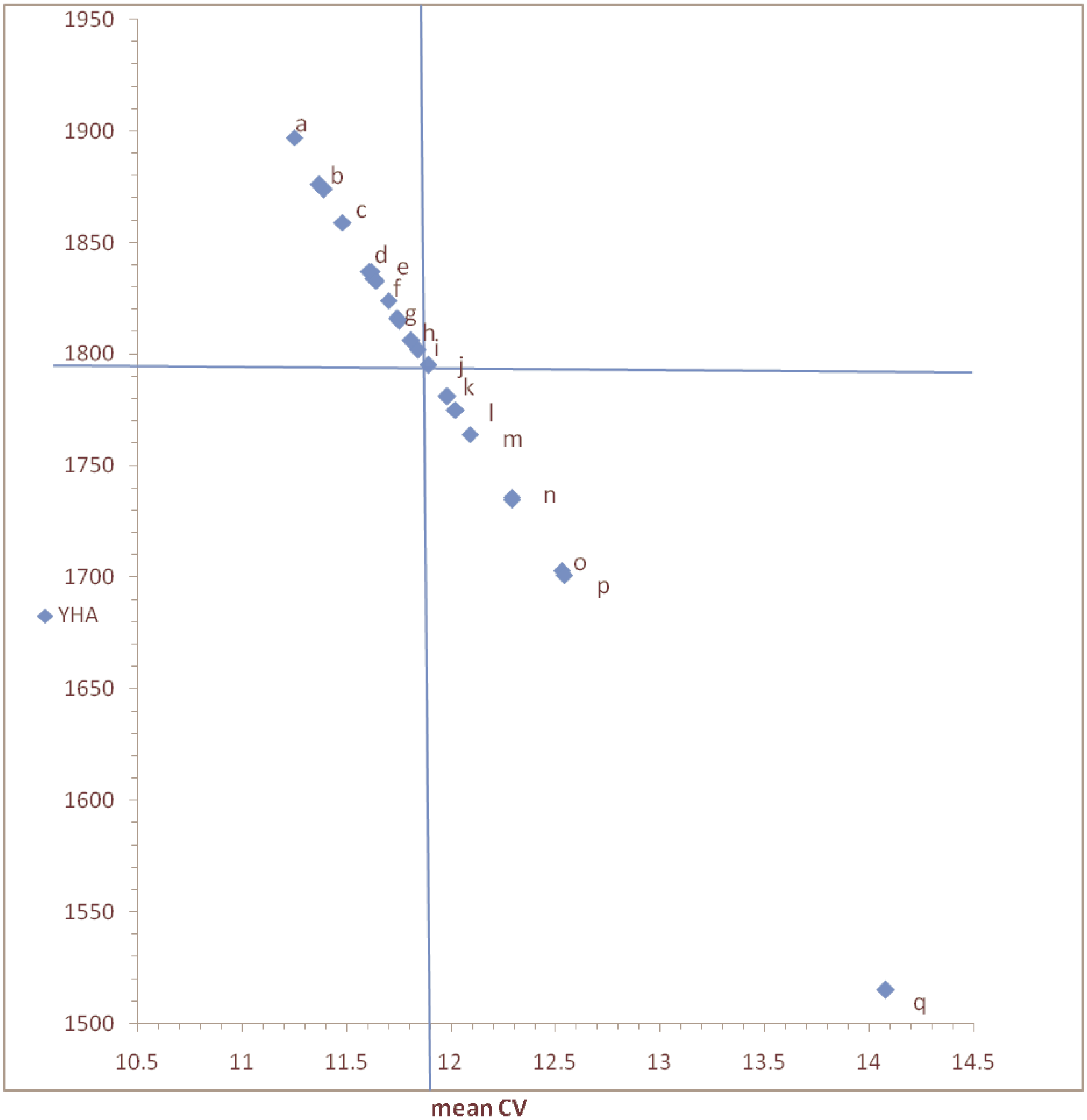


Figure 2: MEAN YIELD VS CV (GENOTYPE-GROUPING TECHNIQUE)

Key:

a: SZ3-1-B-B	f: SZ3-2-B-B1	k: LY1-7-B	p: SZP
b: LY1-2-7-B, CA15,	g: LY2-3-B, SZ3	l: LY2-6-B, LY4-4-B	q: CA38
c: SZ9-7-B-B	h: LY1-2-B	m: SZ9-B-B-B2	
d: CA9,LY2-8-B,SZ3-3- B-B2	i: CA18	n: LY-P, LY2-2-B	
e: CA24, CA3,SZ9-B-B-B1	j: SZ4-B-B	o: CA-P	

Table 11: Genotype Stability Groups

Group	Genotype classification	Line
1	High yielding, small variation	CA15, CA18, CA24
		CA3, CA9
		LY1-2-B, LY2-3-B
		LY2-7-B, LY2-8-B
		SZ3-1-B-B, SZ9-7-B-B
		SZ3-2-B-B_1, SZ9-B-B-B_1
		SZ7-4-B-B, SZ3,
		SZ3-3-B-B_2
2	High yielding, large variation	Nil
3	Low yield, small variation	Nil
4	Low yield, large variation	SZ-PARENT, CA-PARENT, LY-PARENT
		CA38
		LY1-7-B
		LY2-2-B
		LY2-6-B
		LY4-4-B
		SZ9-B-B-B2

5.0 DISCUSSION

In this study most mutants yielded the same as their parent line. This was an unexpected result as it was expected that the mutation derived lines would generally perform better than their respective parent lines. It could be that the parent lines performed better under high management at the research stations as opposed to when grown under local conditions. This better management was inclusive of fertilizer application. This is often absent among small scale farmers. This is supported by Bezuneh (1992) who, in his study on risk-efficient management strategies, found that the Brazilian Carioca bean variety when used in combination with fertilizer and insecticide performed better than without. In contrast, Kimani (1988) found that M6 mutant lines derived from Canadian Wonder bean variety showed an increased grain yield of 11% over their parent. On the whole, they performed better than their parent. The Francis and Kannenberg stability analysis however showed that most of the mutation derived lines were high yielding. This implies that though the lines were not higher than their parent lines in terms of yield, they were however high yielding. Going by the findings of Svetleva (2005) that yield is one of the most important factors that influence cultivar choice among farmers this implies that the high yields seen in the lines in this study would make them preferred choices by local farmers. Farmers would expect higher productivity and returns with these lines. A unit of land would produce more for the same amount of labour. This is supported by Bezuneh (1992) who observed that a higher productivity would result in increased incomes and food security. All CA mutant lines had shorter days to maturity than their parent. They matured earlier on the average by 6 days. CA38 and CA9 flowered earlier than their parent by 2.5 days. SZ3-3-B-B2 had a longer pod length than its parent of 125.83mm. This indicated that these mutant lines had higher performance in terms of these characters. Kimani (1988) established in his study on bean improvement that in addition to yield increase, the mutant lines he evaluated also showed increased 100 seed weight and reduced days to maturity. This is important for farmers who desire varieties that are top performers in a number of agronomic aspects. Very often, these provide the greatest returns to inputs. Though most of the lines were at par with their parent in terms of yield per hectare, they possessed other qualitative characteristics which could make them more desirable than their parent. These included traits such as seed coat colour, nutritional content, and cooking time. These are characteristics which are being studied in the on-going legume improvement programme at the School of Agricultural Sciences at UNZA. Among all the lines studied, none had a lower yield than the parent. These lines could be crossed with other varieties that posses other desirable traits to come up with improved genotypes. Micke (1993) reported the use of desired variants from large mutant populations to breed better cultivars of beans by way of crossing with other existing lines. These lines can still be recommended for cultivation in the specific sites at which they showed good performance. CA 15, CA18 and CA24 for instance had a high average yield at Chafukuma (Solwezi) of 1899 kg/ha. LY1-7-B and LY2-2-B had an average yield at Chafukuma of 1837 kg/ha while SZ3 and SZ3-1-B-B had an average yield in the same location of 1922 kg/ha. Such yields would still be desirable for farmers. The recommendation of lines for cultivation in specific sites at which they can perform well is supported by Horner and Frey (1957) who showed that the GxE interaction can be reduced by stratification of the environment and allocations of different genotypes to different environments. The above lines (CA 15, CA18, CA24, LY1-7-B, LY2-2-B, SZ3 and SZ3-1-B-B) performed highly at Chafukuma and could be recommended therefore for region III of the agro-ecological zones of Zambia. It is possible that these lines are responsive to high rainfall (> 1000mm per annum) and show signs of tolerance to high acidity and aluminum toxicity. Thung and Rao (1999) found that common beans is relatively more sensitive to high acidity than other crops while Beebe (2004) found that aluminum toxicity resulted in a bean yield decrease of 40%. This worker also determined that acid tolerance in beans is associated with root traits. He suggested matching the root system to the environment as a possible route for achieving acid tolerant lines. Crossing these lines with other stable lines would give rise to lines that are both stable and with tolerance to acidity. Tolerance of crops to acidity is a very desirable trait in agro-ecological region III of Zambia where high rainfall entails the presence of highly weathered and leached soils. These soils have a low pH of less than 4.5 and very low reserves of primary minerals (Bunyolo et al, 1995). These workers further observed that these soils are largely deficient in phosphorus, nitrogen and many other major plant nutrients and some micronutrients.

This is a major constraint to high productivity in Northwestern, Northern, Copperbelt and Luapula provinces of Zambia. This affects both legumes and cereals. Acid tolerant crops would be a major way forward and would be more accessible to small scale farmers rather than the use of expensive inputs such as lime which are largely difficult to access and even handle.

Sixteen of the mutation derived lines were found to be high yielding and stable using the Francis and Kannenberg genotype grouping technique. This included all SZ mutants except SZ9-B-B-B2 and all CA mutants except CA38. The following lines were found to be stable among the LY mutants- LY2-3-B, LY2-7-B and LY2-8-B. The mean yield over the different environments was indicative of the average performance level that a cultivar can be expected to maintain if grown again in a similar range of environments. The stability analysis however went further to point out those lines that would perform consistently highly. This represents a very desirable combination of traits by small scale farmers. Farmers want to be assured of high yields irrespective of which agro-ecological region their bean crop is being grown in. With such varieties, stability would not be an issue in terms of cultivar choice but this would instead be influenced by other qualitative characters of interest such as seed coat colour, seed size, cooking time, disease and pest resistance. Cultivar choice would be based on consumer preferences and market demands. The stable lines can be grown successfully in agro-ecological regions II and III. The unstable mutant lines which were, CA38, LY1-7-B, LY2-2-B, LY2-6-B, LY4-4-B and SZ9-B-B-B2 can be recommended to be grown in locations in which they performed highly. However due to their instability and large variation they may not yield as highly in the event of fluctuations in environmental factors. Solwezi Rose parent, Lyambai parent as well as Carioca parent were found to be unstable. This meant that they had a low yield and large variation. Solwezi Rose for instance is grown mostly in the Northwestern Province of Zambia and especially in Solwezi. This variety does not perform very well when grown elsewhere even within the same agro-ecological region. When grown in the neighbouring districts of Kasempa and Mufumbwe for instance Solwezi Rose parent, which performs highly in Solwezi district (800kg/ha), has a very low performance of 300kg/ha. Thus there is only minimal production of beans in these areas. The yield stability offered by the mutant lines would present a solution to this predicament so as to enable communities in non beans growing areas harness the nutritional advantages offered by beans. If these beans are grown locally, they can then be accessed at cheaper prices. The yield instability exhibited by the parent lines is consistent with the conclusion made by Bezuneh (1992) that most existing varieties have low yields and are unstable.

On the whole therefore, it was seen that though the mutant lines were not significantly higher in yield than their respective parents, the variation created by induced mutation resulted in mutation derived lines that performed higher than their parent in terms of yield stability. This is in agreement with other yet to be published results under the Legume Improvement Program at UNZA, School of Agricultural Sciences, Department of Crop Science. Largely, the mutants have proved to be more superior to their parent lines in a number of traits. It is clear that the results of this study, will contribute to addressing the numerous challenges of beans production. With the increase in human population growth and consequently demand, these high yielding and stable cultivars can offer more reliable production levels that are able to satisfy the growing nutrition demands. According to the unpublished work of Chika and Munyinda (2010), who worked on the same genotypes that are being considered in this study, the mutant lines exceeded their parent lines in terms of nutritional levels. These studies revealed that the mutant lines had greater contents of protein, fat, calcium, iron, manganese, phosphorus, potassium and zinc. The mutant lines had a range of 21-23% protein while the parent lines had 19.5% to 20% protein content. SZ7-4-B-B, LY1-2-B, LY2-3-B, and CA38 were found to have protein contents of 25.5%, 26%, 23.3% and 21.8% respectively. SZ3-1-B-B was found to have a high iron (Fe) content of 7.45 mg/100g as compared to its parent which had 5.4mg/100g. The mutants had a fat content of up to 2.05% while their parents did not exceed a fat content of 1.8%. The mutants were also found to have a significantly higher micronutrient content of 1460-1830 mg/kg while their parent lines only had a micronutrient content of 1660-1750 mg/kg. Thus these mutant lines can contribute greatly to combating malnutrition in Zambia especially that related to micronutrient deficiencies. On the whole, these mutant lines would significantly deal with the challenges arising from a high nutritional demand due to a rising population. It is very important that the performance of these lines in terms of nutritional content be tied to their performance in terms of yield and stability as well as to all other traits being studied in the program. This is because a line that has high yield and stability but with very low nutritional content, may not be very desirable as the gains in yield performance would be lost in the reduction in nutritional content. It is important to establish these associations between increases in yield to other desirable traits as these could offer useful interventions in the breeding program. However the positive results in a number of traits have indicated useful positive correlations of most traits with yield and stability. The higher performance in terms of yields denotes that overall production can be increased without necessarily increasing the area under cultivation. This addresses the issue of land scarcity which is slowly becoming a world wide concern.

On going studies in the Legume Improvement Program have also shown evidence of pest tolerance among some of the mutation derived beans lines. In their yet unpublished work, Munyinda and Zulu (2010) found that CA 38 was tolerant to bruchid attack as compared to the parent which is not. Further studies in this respect need to be conducted to establish the pest and disease resistance of these mutants. This would greatly address the challenge of yields in beans being suppressed by its susceptibility to pests and diseases. Other useful findings in the on going studies have established that all the mutants except CA15 fixed more Nitrogen than their parents.

6.0 Conclusion

The study revealed that the treatment mean yields of the mutant lines were significantly different from each other. The site differences in mean yields per hectare were also significantly different from each other. The effect of the site by line interaction was as well found to be significant ($p \leq 0.01$). Although the mutant lines were found to have similar grain yield per hectare as their respective parent lines, the Francis and Kannenberg genotype grouping technique established that these were high yielding. A number of the lines were found to perform highly in a specific environment and can thus be recommended for production in those areas. The lines CA 15, CA18, CA24, LY1-7-B, LY2-2-B, SZ3 and SZ3-1-B-B had high yields at Chafukuma and can thus be recommended for production in region III of the agro-ecological regions of Zambia. All the CA mutant lines matured earlier than their parent line by 6 days. CA38 and CA9 flowered earlier than their parent by 2.5 days. The stability analysis of Francis and Kannenberg (1978) revealed that the following lines had yield stability (high yielding, small variation) : CA15, CA18, CA24, CA3, CA9, LY1-2-B, LY2-3-B, LY2-7-B, LY2-8-B, SZ3-1-B-B, SZ9-7-B-B, SZ3-2-B-B1, SZ9-B-B-B1, SZ7-4-B-B, SZ3, SZ3-3-B-B2. These can be recommended for production in both agro-ecological regions II and III where they can be expected to perform with predictable and stable yields. On the other hand, the following lines were found not to be stable (low yielding, large variation): SZ-PARENT, CA- PARENT, LY-PARENT, CA38, LY1-7-B, LY2-2-B, LY2-6-B, LY4-4-B and SZ9-B-B-B2. This was an expected result for the parent lines. The mutant lines that were found not to possess yield stability can be crossed with other lines to develop improved lines. On the whole, it was seen that most of the mutation derived lines of common beans were superior to their parent lines Lyambai, Carioca and Solwezi Rose beans in terms of yield stability. This high performance would be important in addressing most of the challenges currently being experienced in beans production as well as contributing to food security in rural communities. The mutant lines would as well be useful in terms of other traits for which they were found to perform better than their respective parent in other accompanying studies to this experiment in the Legume Improvement Program. These include high protein content, high nutritional composition for macro and micronutrients, tolerance to pests and diseases, tolerance to acidity as well as high nitrogen fixing ability. The mutant lines can be released as varieties or can be crossed as sources of desirable traits to develop other lines.

Recommendation

The new lines need to be subjected to researcher designed on-farm trials to establish their performance under farm conditions. These can subsequently be released as varieties. Studies also need to be conducted to establish the interrelationship of yield and yield components in the mutant derived lines.

LITERATURE CITED

Akande S.R. and M.O. Balogun (2003). Institute of Agriculture Research and Training. Basf Wye: Crop Science 8: 209

Ali N., F. Javidfar and Y. Mirza (2003). Selection of Stable Rape Seed Genotypes Through Regression Analysis. Crop Science 5: 72

Allard R.W. and A.D Bradshaw (1964). Implications of Genotype-environmenral Interactions in Applied Plant Breeding. Crop Science 4:503

Assefa H. and S.Gebeyehu (2003). Genotype x Environment Interaction and Stability Analysis of Seed Yield in Navy Bean Genotypes. African Crop Science Journal vol.II, no. 1, pp 1-7.

Ayehal E. (1988). Evidence of Yield Stability in Selected Landraces of Bean (Phaseolus vulgaris L). Experimental Agriculture. Cambridge University Press, 24: 367-373.

Beebe S. (2004). Proceedings of the 6th International Symposium on Plant-Soil Interactions at Low pH. Japanese Society of Soil Science and Plant Nutrition, Sendai: 272-273.

Benzuneh M. (1992). Application of Stochastic Dominance Criteria to Evaluate Bean Production Strategies in Central Province of Zambia. Agricultural Economics, Elsevier Science, vol 7, pp 289-299.

Bunyolo A., B. Chirwa and M. Muchinda (1995) Agro-ecological and Climatic Conditions. Berlings,Arlov,Stockholme.

Clever A.G. and D.H Scarisbrock (1991). An Introduction to the Principles of Crop Experimentation. BASF Wye College.

Cochran W.G and G.M. Cox (1957). Experimental Designs. John Wiley and Sons Inc., New York, N.Y. pp 545

Comstock R.E. and R.H Moll (1963). Genotype-Environment Interactions. National Academy of Science, Publication no.982; Washington D.C

Duke J.A (1983). Handbook of Legumes of World Economic Importance.Plenum Press. New York

Eberhart S.A and W.A. Russel (1966). Stability Parameters for Comparing Varieties. Crop Science 6: 36-40.

Fageriaa N.K. and A.B Santosa (2008). Journal of Plant Nutrition, vol 31, Issue 6, pp983-1004.

Francis T.R. and L.W. Kannenberg (1978). Yield stability studies in short-season maize. A descriptive method for grouping genotypes. Plant Science 58:1032

Freeman G.H. and J.M. Perkins (1971). Environment and Genotype –Environmental Components of Variability. Heredity 27: 15-23

Gomez K. and M. Gomez (1984).Statistical Procedures for Agricultural Research, John Wiley and Sons.

Gridleya H.E. and S.M Musanab (1996). Field Crops Research. Vol 46, Issues 1-3, pp153-159.

Growing and Selling Beans, Information Pack (SIDA/MACO), 2000.

Herbert Y. and C. Plomien (1995). Genotype x Environment Interaction for Root Traits in Maize as Analysed with Factorial Regression Models. Euphytica 81:85-92

Hills F.J. and T.M. Little (1978). Agricultural Experimentation Design and Analysis. John Wiley, Canada.

Horner T.W. and K.J. Frey (1957). Methods for Determining Natural Areas for Oat Varietal Recommendations. Agron. J. 49:313-315

Kaplan L.T.S and J.R Smith (1973). Early Cultivated Beans from an Intermutane Peruvian Valley,Science pp76-77

Kelly J.S (1972) Horticultural Science, FAO Proceedings.

Kelly J.D., M.W. Adams and G.V. Varner (1982). Yield Stability of Determinate and Indeterminate Dry Bean Cultivars. Journal TAG, Vol. 74, number4.

Kimani P.M (1988). Improvement of Food Beans (*Phaseolus vulgaris L.*) Through Mutation Breeding. Acta Hort. (ISHS) 218:251-260.

Konzak C.S., R.N Milan, E. Edith and R.J. Foster (1964). Factors Affecting the Biological Action of Mutagens. Symposium on Mutation, Prague (In Press).

Horticulturea Brasileira,(2002)vol 20, No. 4, Pp. 616-618

Lacandula M. and X.J. Mari (2004) http://www.manilatines.net.national

Lefers M. (2004).Biochemistry,Northwestern, J. Agricultural Science Vol 11: 233.

Legume Improvement Preliminary Report (2006), Department of Crop Science, Unza.

Lin C.S., M.R. Binns and L.P. Lefkovitch (1986). Stability Analysis: Where do We Stand? Crop Science 26:894-900.

Micke A. (1993). Plant Breeding and Genetic Section, Joint FAO/IAEA Division, Vienna. Kluwer Academic Publishers.

Moll R.H. and C.W Stuber (1974). Quantitative Genetics- Empirical Results Relevant to Plant Breeding. Adv. Agro 26:277-314.

Montelone B. (2004). Division of Biology, Mutagens, Kansas State University, pp 193

Muchindu M.R. (1985). The Agricultural Climates of Zambia. An Agro- meteorological Report No.9. Meteorological Department, Lusaka, Zambia.

Mulila J.M and F. Javaheri (1994). Food Legumes Review Paper, Mount Makulu Research Station, Lusaka.

Muliokela S.W (1995) Zambia Seed Technology Handbook Berlings,Arlov,Stockholme.

Mwale V.M., J.M Bokosi and C.M Masangano (2008). Yield Performance of Dwarf Bean Lines Under Researcher Designed Farmer Managed System in Three Bean Agro-ecological zones of Malawi. African Journal of Biotechnology, Vol. 7, 2847-2853.

Omidi A.H. (2008). Seed and Plant Improvement, Safflower. Wsu.edu.

Santos B.J., A.M. Vello and M. Ramalto (1982). Rev. Brasil Genet. Vol 4, 761-772.

Shukla G.K. (1972). Some Statistical Aspects of Partitioning Genotype-environment Component of Variability. Heredity 29:237-245

Singh B.D (1983) Plant Breeding Principles and Methods, Kalyani Publishers, Ludhiana.

Thung M. and I.M. Rao (1999). Integrated Management of Abiotic Stress. Kluwer Academic Publishers, Dordrecht, pp 331-370.

Yates F. and W.G. Cochran (1938). The Analysis of Groups of Experiments. J.Agric.Sci (Camb.) 28: 556-580

Appendix 1 Analysis of Variance for Yield/hectare

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	5	507636.	101527.	2.23	
Rep.*Units* stratum					
Site	2	443443.	221722.	4.87	0.008
Lines	24	2578391.	107433.	2.36	<.001
Site.Line	48	4342147.	90461.	1.99	<.001
Residual	370	16845301.	45528.		
Total	449	24716918.			

Appendix 2 Analysis of Variance for Days to 50% Flowering

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	5	18.258	3.652	2.31	
Rep.*Units* stratum					
Site	2	10.031	5.016	3.17	0.043
Lines	24	490.778	20.449	12.94	<.001
Site.Lines	48	93.969	1.958	1.24	0.143
Residual	370	584.742	1.580		
Total	449	1197.778			

Appendix 3 Analysis of Variance for Days to Maturity

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	5	190.251	38.050	4.95	
Rep.*Units* stratum					
Site	2	15.591	7.796	1.01	0.364
Lines	24	1412.209	58.842	7.65	<.001
Site.Lines	48	362.631	7.555	0.98	0.511
Residual	370	2845.916	7.692		
Total	449	4826.598			

Appendix 4 Analysis of Variance for Hundred Seed Weight

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	5	845.51	169.10	1.72	
Rep.*Units* stratum					
Site	2	25227.75	12613.88	128.44	<.001
Lines	24	24997.26	1041.55	10.61	<.001
Site.Lines	48	8725.58	181.78	1.85	<.001
Residual	370	36336.16	98.21		
Total	449	96132.26			

Appendix 5 Analysis of Variance for Pod Length

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	5	626.7	125.3	0.87	
Rep.*Units* stratum					
Site	2	758.4	379.2	2.63	0.074
Lines	24	25267.0	1052.8	7.30	<.001
Site.Lines	48	4786.0	99.7	0.69	0.941
Residual	370	53392.8	144.3		
Total	449	84830.9			

Appendix 6 WEATHER DATA FOR THE 3 SITES

Weather Data- Misamfu

YEAR	MONTH	RAINFALL(mm)	TEMPERATURE (degrees celcius)		RH (%)
			MAX	MIN	
2008	OCT	29	32.5	16.3	50
2008	NOV	203.4	29.5	16.9	70.8
2008	DEC	126.1	27.7	16.6	
2009	JAN	99	27.7	16.3	81.2
2009	FEB	281.3	26.9	15.8	*
2009	MAR	220.9	27.6	16.1	80.3
2009	APRIL	104.8	26.8	14.1	74
2009	MAY	22.5	26.9	12.7	71.7

Weather Data-GART

YEAR	MONTH	RAINFALL(mm)	TEMPERATURE (degrees celcius)		RH (%)
			MAX	MIN	
2008	OCT	53.3	31.6	14.1	48.2
2008	NOV	105.5	29.4	15.5	61.8
2008	DEC	198.2	26.7	16.7	74.8
2009	JAN	258.4	26.1	17	77
2009	FEB	60	26.4	16.1	75
2009	MAR	119.4	31.8	16.4	75
2009	APRIL	0	24.9	13.4	*
2009	MAY	39.1	24.9	12.3	

Weather Data- Chafukuma					
			TEMPERATURE		RH
YEAR	MONTH	RAINFALL(mm)	(degrees celcius)		(%)
			MAX	MIN	
2008	OCT	64.5	31.7	18.1	53.1
2008	NOV	301.1	27.1	18.5	*
2008	DEC	264	27.2	17.7	*
2009	JAN	198.3	27.9	17.7	81.9
2009	FEB	*	27	17.2	*
2009	MAR	244.1	27	22.5	80.7
2009	APRIL	40.4	26.6	13.3	70.8
2009	MAY	35	26.7	12.4	63.6

* Data not available

Appendix 7 Field Layout

T23	T1	T5	T13	T11
T7	T19	T2	T25	T3
T4	T15	T12	T10	T17
T21	T16	T22	T6	T8
T14	T18	T24	T9	T20

Rep 1

T18	T15	T25	T10	T14
T2	T19	T7	T9	T23
T24	T20	T11	T6	T13
T16	T5	T21	T4	T3
T1	T22	T8	T17	T12

Rep 2

T12	T16	T21	T8	T1
T6	T11	T24	T17	T5
T9	T22	T25	T4	T3
T14	T13	T20	T7	T2
T18	T10	T15	T23	T19

Rep 3

T21	T19	T13	T3	T15
T12	T5	T4	T18	T10
T23	T25	T20	T6	T2
T24	T1	T17	T16	T7
T8	T9	T14	T11	T22

Rep 4

T9	T7	T23	T2	T16
T17	T4	T8	T3	T6
T13	T22	T10	T14	T12
T18	T15	T19	T24	T11
T25	T20	T1	T5	T21

Rep 5

T24	T22	T18	T17	T4
T14	T3	T2	T1	T20
T15	T5	T23	T8	T9
T12	T10	T19	T21	T25
T11	T16	T13	T7	T6

Rep 6

* Note :T-Treatment (This represents the 22 mutant lines plus 3 parents)