

**PATH AND STABILITY ANALYSES OF YIELD AND YIELD COMPONENTS
OF SOYBEAN (*Glycine max.* L Merr.) VARIETIES INTERCROPPED WITH
MAIZE**

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Degree in Master of Science in Plant Breeding in the School of Agriculture and
Enterprise Development, Kenyatta University.**

July, 2018

DECLARATION

I, Wanyama, Patrick Wanjala, declare that this thesis is my original work and has not been presented for award of a degree in any other university or any other award.

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DEDICATION

I dedicate this study to my wife; Gaudencia and sons; Victor and Benedict for their support, love and encouragement.

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LIST OF ABBREVIATIONS AND ACRONYMS

α	Alpha
$^{\circ}\text{C}$	Degrees Celsius
%	percent
ANOVA	Analysis of variance
cm	Centimeters
g	grams
KALRO	Kenya Agricultural and Livestock Research Organization
Kg	Kilograms
KSH	Kenyan shillings
LER	Land Equivalent Ratio
m	Meter
m^2	Squared meter
mm	Millimeters
MT	Metric Tonnes
SAS	Statistical Analysis System
WACE	Weeks after crop emergence

ABSTRACT

Soybean production in Kenya is estimated at 9,061MT. This is low compared to the annual demand of 100,000MT. This large deficit is met through importation which puts a strain to the economy's foreign exchange. Soybean has the highest protein content (40-42%) among the food crops with oil content of 18-22% comprised of 85% unsaturated fatty acids. These attributes make it an inexpensive source of proteins and desirable human diet. Released soybean varieties in Kenya have been evaluated based on sole-cropping system. However, commercial production is mainly through intercropping with either maize or sugarcane. The most common advantage of intercropping is the production of greater yield on a given piece of land by making more efficient use of the available growth resources. Research on intercropping has been concerned with effects of agronomic manipulation but there is limited information on soybean varieties suitable for intercropping. Therefore, this study aimed to compare grain yield and yield components of soybean under intercropping and sole cropping, select varieties of soybean for increased yields under intercropping and to determine the genotype by environment interaction in soybean. The study was conducted in three sites: KALRO-Alupe, in Busia County; KALRO-Kakamega, in Kakamega County; and Sang'alo Institute of Science and Technology, in Bungoma County. Ten recommended varieties of soybean were evaluated in randomized complete block design in split plot arrangement with three replications. The main plots were cropping systems (soybean sole crops and maize-soybean intercrop); the sub plots were the ten soybean varieties. The maize variety used was H513. Data was collected on grain yield and yield components of soybean. All measured variables were statistically analyzed by ANOVA using SAS software. Treatment means were separated using the LSD at $\alpha = 0.05$. The results indicated that the yield and yield components were significantly different between the varieties in each site and in combined environment. In intercrops, the varieties were significantly different in all three sites; Kenysoy009, DPSB8, DPSB19 and EAI3600 were the best varieties in Alupe, Kakamega, Sang'alo and combined environments respectively. In sole cropping system DPSB8, SC Saga, Salama and Kensoy009 were the highest yielding varieties in Alupe, Kakamega, Sang'alo and across sites respectively. Across the environments under intercropping system, harvest index, 1st pod height and leaf area were positively correlated to grain yield while days to maturity were negatively correlated with yield. In path analysis, the number of branches had the highest direct effect of 0.55 followed by harvest index of 0.35. However, days to maturity had negative direct effect on grain yield. Therefore, an early maturing variety with many branches and high harvest index should be selected for intercropping. In sole cropping system; 1st pod height and number of leaves were negatively correlated to grain yield while the other characters were positively correlated to grain yield. Path analysis in sole crops indicated that seeds per pod had the highest direct effect of 0.60 followed by 100 seed weight. Therefore, seeds per pod and 100 seed weight should be considered when selecting varieties for sole cropping system. The highest yielding varieties for intercropping were EAI3600 and DPSB19 and therefore are recommended for intercropping by farmers.

CHAPTER ONE

INTRODUCTION

1.1 Background Information

Soybean production in Kenya is estimated at 9,061 metric tonnes (MT) (FAO 2016). This is low compared to the annual demand of 100,000MT (Soybean Production and Marketing Strategy, 2009). The large deficit is met through importation which puts a strain to the economy's foreign exchange. About 90% of the soybean is used in animal feed processing while 10% is used for human food processing and direct consumption (Chianu *et al.*, 2008).

Soybean has the highest protein content (40-42%) among the food crops with oil content of 18-22% which comprises of 85% unsaturated fatty acids (Antallina, 1999). Furthermore soybean is known to lower the risk of heart disease, breast, colon, and prostate cancer as well as relieve menopause symptoms and lactose intolerance. These attributes makes it an inexpensive source of proteins and desirable human diet (Jagwe and Nyapendi, 2004).

Promiscuous soybean has the ability to fix nitrogen and provide biomass that can be integrated as organic mulch thereby increasing soil fertility (Sanginga *et al.*, 2003). This may lead to substantial savings in fertilizer costs. Soybean is relatively drought resistant and makes efficient use of available water resources (Chianu *et al.*, 2008) which makes it suitable for production in both short and long rain seasons and therefore can contribute towards food security in Kenya.

Intercropping has been shown to have several advantages over sole cropping. These include, better utilization of available resources compared to sole crop of the mixture (Willey,1979; Tsuboet *al.*, 2003) and is an insurance against crop failure in the case of adverse condition such as frost, drought, pest and disease attack where one crop may be harvested when the other fails (Clawson, 1985).

Yield advantage has been reported from intercropping system compared to sole cropping (Beena, 1985, Thole, 2007, Mucheru-Muna *et al.*, 2010, Mosoumen and Mansour, 2012). However, intercrops show both intra-specific and inter-specific competition (Rao *et al.*, 1979). Ijoyah *et al.*(2013) showed that soybean-maize intercropping reduced soybean yield by 43.3%. This can be minimized by choice of appropriate crop varieties besides agronomic manipulation of the intercrops. However, maize yield was not significantly affected when intercropped with soybean (Ijoyahet *al.*, 2013).

Maize is the staple cereal in Kenya and may be intercropped with beans, soybean or cowpea. The root system of the cereal-pulse intercrop acquires water and nutrients from different soil layers. This results in better utilization of limited resources. Competition for resources depends on developmental characters and growth system. These should modify expression of yield and yield components in both inter and intra-cropping system.

Soybean trials in sole cropping have shown that yield has a positive correlation with 100 seed weight (Ghodrati *et al.*, 2013; Okonkwo and Idahaso, 2013). It is also reported

to have a positive relationship with total dry matter as well as harvest index (Aditya *et al.*, 2011) and number of pods per plant (Abady,*et al.*,2013; Shaahu *et al.*, 2013). However, a negative correlation has been reported between yield and first pod height (Shaahuet *al.*, 2013). On the other hand, correlation between yield and days to maturity has contrasting reports, Ghodrati *et al.*, (2013) reported a negative correlation while Ariyo (1995) and Abady *et al.*, (2013) reporting positive correlation.

1.2 Statement of Problem

Released soybean varieties in Kenya have been evaluated based on sole-cropping system. However, commercial production is mainly through intercropping with either maize or plant sugarcane (Tinsley, 2009). Research on intercropping has been concerned with effects of agronomic manipulation; therefore limited information on soybean varieties suitable for intercropping is available. A number of studies indicated major differences in cultivar performance under different agronomic systems such as intercropping (Sharma and Mehta, 1988; O’Leary and Smith, 1999; Yadav and Yadav, 2001). Traits to be considered under sole cropping do not necessarily have the same effect under intercropping. Setegn *et al.* (2006) when evaluating genotype by cropping system of climbing beans with maize reported that maintenance of large number of seeds per pod and highest harvest index were determinants of seed yield under intercrop conditions while the number of pods per plant and seed weight appeared to the traits to consider under sole cropping.

The evaluation of the genetic material developed for monoculture may be insufficient to identify suitable genotypes for intercropping (Francis and Smith, 1985). However,

some reports about positive correlations between yields in sole crop and intercrop (Holland and Brummer, 1999) raised the question of the indirect selection in another cropping system (such as monoculture) that could also lead to varieties that satisfy the demands of intercropping. Plant characters that are considered to be useful in monoculture may not be so under intercropping and there is a need to clarify the plant traits that promote intercropping advantage. According to Davis and Woolley (1993) the traits required for intercropping are those which enhance the complementary effect between species and minimize the intercrop competition. A breeding system targeted for intercropping must cover a large area, and be sufficiently unique to justify a separate breeding program (Davis and Wooley, 1993) because the choice of compatible crops differ from place to place (Singh, 1979). This implies that intercrops should be assessed in different areas to ascertain their stability. It is therefore important that as part of breeding programme aimed at producing a genotype suitable for one or more cropping system, the desirable characters for each crop must be included in the selection criteria. This study therefore aims to identify variety characters that reduce competition between species and confer yield advantage in soybean under maize-soybean intercrop.

1.3 Objectives

1.3.1 Broad Objective

To increase the yield of soybean under maize-soybean intercropping system.

1.3.2 Specific Objectives

1. To compare grain yield and yield components of soybean under intercropping and sole cropping.

2. To identify varieties of soybean for increased yields under intercropping.
3. To determine the stability of soybean in both sole cropping and inter cropping.

1.4 Hypotheses

1. There are no differences in grain yield and yield components of soybean under sole cropping and intercropping system.
2. There are no soybean varieties suitable for intercropping.
3. There is no stable soybean varieties for sole cropping and inter cropping.

1.5 Justification of the Study

Released varieties of soybean have been assessed based on sole cropping system. However, production in Kenya is mostly by intercropping with maize or sugarcane among others. Studies on intercropping have been based on agronomic manipulations. Intercropping causes both competition and complementation between species; therefore this study will seek to identify the characters in soybean that should be considered when selecting varieties for intercropping with maize which reduce competition and increase complementary effects leading to increased yield in the intercrops and identify varieties suitable for intercropping.

1.6 Significance of Study

Information from this study will provide plant breeders with characters to select for when developing soybean varieties for intercropping. It will also provide farmers and

extension officers with the best soybean to intercrop with maize among the released varieties for maximum yields in the different regions.

CHAPTER TWO

LITERATURE REVIEW

2.1 Intercropping

Intercropping is the agricultural practice of cultivating two or more crops in the same space at the same time (Ofori and Stern, 1987). The component crops of an intercropping system do not necessarily have to be sown at the same time nor do they have to be harvested at the same time, but they should be grown simultaneously for a great part of their growth periods. In intercropping, there is normally one main crop and one or more added crop(s), with the main crop being of primary importance for economic or food production reasons. The two or more crops in an intercrop normally are from different species and different plant families, or less commonly they may be simply different varieties or cultivars of the same crop, such as mixing two or more kinds of soybean seed in the same field.

2.2 Intercropping Row Configurations

In an intercrop system, row configurations alter the amount of light transmission to lower layers of the crops and affect the competition of species for light, water, and nutrients. There are four types of intercropping row configurations: (i) mixed intercropping, which grows component crops simultaneously in complete mixtures; (ii) row intercropping, which grows component crops simultaneously in different rows; (iii) strip intercropping, which grows component crops simultaneously in different strips; and (iv) relay intercropping, which grows component crops in relay so that growth

cycles overlap (Andrews and Kassam, 1976). Mucheru-Muna determined that planting two rows of legume crop between two rows of maize results in higher yields than in-row intercropping.

2.3 Yield Advantages of Intercrops

The most common advantage of intercropping is the production of greater yield on a given piece of land based on land equivalent ratios (Willey, 1979; Li *et al.*, 1999; Hauggaard-Nielsen and Jensen, 2001; Mucheru-Muna *et al.*, 2010). This is achieved by making more efficient use of the available growth resources using a mixture of crops of different rooting ability, canopy structure, height, and nutrient requirements based on the complementary utilization of growth resources by the component crops (Midmore, 1993; Tsubo *et al.*, 2001).

Selection of genotypes to minimize competition effects and maximize complementary effects is relevant in intercropping. This can be achieved by crops that differ in growth duration (Fukai and Trenbath, 1993; Rao and Willey, 1980). This enables late maturing crops to recover from possible damage caused by the quick maturing crop component (Keating and Carberry, 1993). Rao and Willey (1980) concluded that the highest Land Equivalent Ratio (LER) was achieved when long duration pigeon pea was intercropped with quick maturing setaria and the lowest with slow maturing sorghum. In contrast when component crops have similar growth duration, their peak requirements occur at the same time and competition is most intense (Fukai and Trenbath, 1993).

Intercrop efficiency in the utilization of environmental resources is also achieved when components differ in space for instance when the leaf canopies of intercropping occupy

different vertical layers with the tallest components having foliage tolerant to strong light and high evaporation demand and shorter components requiring shade and or high humidity. Intercropping maize with cowpea has been reported to increase light interception in the intercrops compared with maize alone (Ghanbari *et al.*, 2010). In addition mutual avoidance of roots could lead to late developing roots occupying lower soil horizons in the mixture than in the monoculture (Raper and Barber, 1970), leading to acquisition of nutrients from different soil horizons. Furthermore, reduced inter-specific competition can be minimized by growing crops with different nutrient requirement (Aiyer, 1949).

As the genetic resemblance between two individuals increase, their requirements become more similar. It follows that the most intensive competitions are intra-specific and inter-varietal (Sammata and Levins, 1970). However divergent components occupy slightly different ecological niches leading to reduced competition.

2.4 Character Correlation and Path Analysis in Soybean

Correlation coefficient is a statistical measure that is used to find out the degree of relationship between two or more variables. Correlation coefficient measure the mutual relationship between various plant characters and determines the components to be relied upon for genetic improvement of yield. Path analysis is a standardized partial regression coefficient that measures the direct and indirect contribution of various independent characters on a dependent character (Nadarajan and Gunasekaran, 2005).

Studies on mono-cropping show that yield was positively correlated to number of pods per plant (Malik *et al.*, 2006; Ghodrati *et al.*, 2013). Ariyo *et al.*; (1995), Muhammad *et*

al., (1992), and Okonkwo (2013), reported positive relationship between 100 seed weight and grain yield. Most studies report a positive correlation between grain yield and total dry matter and harvest index (Abady *et al.*, 2013; Ghodrati *et al.*, 2013; and Rajkumar *et al.*, 2010). There are contrasting reports on the relationship between yield and first pod height. Ghodrati *et al.* (2013) reported a negative relationship while Mohammad *et al.*, (1992) reported a positive correlation.

In addition, there are conflicting reports on between grain yield and days to maturity. Ariyo *et al.*, (1995), Abady *et al.*, (2013) and Malik *et al.*, (2006) reporting a positive correlation while other researchers have reported negative correlation (Ghodrati *et al.*, 2013 and Rajkumar *et al.*, 2010). Ghodrati *et al.*, (2013) and Rajkumar *et al.*, (2010) reported a negative relationship between yield and days to initiation of flowers while Malik *et al.*, (2006) reported a positive correlation.

A positive relationship was reported between height at harvest and grain yield (Ariyo; 1995) while a negative has also been reported (Rajkumar *et al.*, 2010). Malik *et al.*, (2006) reported negative association between yields with days to 50% flowering. A positive relationship has been reported between number of branches and grain yield (Rajkumar *et al.*, 2010 and Malik *et al.*, 2006). A Study by Ghodrati *et al.*, (2013), reported that total dry matter followed by harvest index had the highest direct positive effect on yield followed by number of pods per plant and days to flowering. Shaahu *et al.* (2013) and Muhammad *et al.* (1992) reported that first pod height had the largest negative direct effect on seed yield. Mohammad *et al.* (1992) reported that plant height had a very high positive direct path followed 100 seed weight. Abady *et al.* (2013),

reported that the number of pods per plant, days to maturity and harvest index had highest direct effect on yield. He further reported that the number of branches and plant height exerted a positive and significant indirect effect on seed yield through number of pods per plant. Malik *et al.* (2006) reported a negative direct effect of leaf area on grain yield. This suggested that selection on the basis of this trait might lead to the loss yield. Ariyo (1995), reported a positive genotypic correlation with number of branches per plant, number of branches per plant and number of flowers per plant.

2.5 Role of Plant Type in Intercropping

The effectiveness of a competitor is an expression of its capacity to make rapid use of immediate supplies and by growth of their roots and foliage to extend the exploitation into a greater spatial part of the environ (Donald, 1962).

A crop variety with high ability to compete for light include; rapid expansion of a tall canopy, larger leaves to minimize penumbra effects (Norman *et al.*, 1971), high allocation of dry matter to building a tall stem (Iwaki, 1959) and rapid stem expansion in response to shading. Rao *et al.* (1980) showed that the number and length of branches and canopy spread constitute important characters in determining relative yield of pigeon pea in sorghum-pigeon pea intercrops.

Hauggaard-Nielsen and Jensen, (2001) in evaluating pea and barley complementarity in intercropping concluded that the choice of pea cultivar in the intercrop influenced intercrop performance to larger extends than the choice of barley cultivar. Furthermore, he concluded that cultivar by cropping system interaction was observed indicating the need to breed suitable cultivars for different cropping systems. Thole, (2007) on

evaluation of soybean varieties adaptability to intercropping under leaf stripped and detasseled maize found out that Magoye variety was not adapted to intercropping. Similarly, Singh, (2016) found that PS 1225 variety had significantly higher yield than others when intercropped with *Populus deltoides*.

2.6 Genotype by Environment Interaction in Crops

Multisite testing refers to a situation of growing the same genotype in many different locations of different climatic and soil properties to evaluate their performance in each of these environments. The aim of this is to maximize the production potential of genotypes in the different environments despite differences in the cultivar ranking from place to place. Genotype by environment interaction makes no genotype to achieve same relative performance in different environment (Baker, 1988).

Growing genotypes in a wide range of environment is used to estimate their stability (Freeman, 1973). It plays an important role in selecting the most adapted genotype for use in target environment (Shrutiet *al.*, (2017). Allard and Bradshaw, (1964) reported that testing genotypes across environments identified genes well adapted to those environments. These will be well buffered varieties that are able to maintain production at high level despite fluctuations in the environment. Selecting these well buffered genotypes is however a difficult task. If there is genotype by environment interaction, the breeder seeks for particular genotype for a specific environment (Falconer, 1989). Genotype X Environment interaction on yield and its components has been studied by several researchers in the past. Radi *et al.*, (1993) evaluated five soybean genotypes

under different locations and years and reported that yield was remarkably affected by varying locations and years. Similarly, *Rao et al.*, (2002) on evaluation of 12 soybean genotypes found significant genotype, year, and location interaction effect of seed yield. According to Eberhart and Russell (1966) joint linear regression analysis, genotypes with high mean yield, low regression coefficients ($b=1$) and non-significant deviation from regression are the most stable. Genotypes with $b>1$ are the ones which are specifically adapted to favorable environments, and genotypes with $b<1$ are specifically adapted to unfavorable environments.

CHAPTER THREE

MATERIALS AND METHODS

3.1 Comparison of Yield and Yield Components under Pure Stand and Intercrops of Soybean in Maize Cropping System.

3.1.1 The Study Sites

The study was conducted from April to August 2015 at three sites that receive bimodal rainfall and whose characteristics are described below.

Table 3.1. Characteristics of experimental sites.

Site	Soil type	Altitude (masl)	Annual rainfall (mm)	Mean temperature °C	Latitude	Longitude
KALRO Kakamega.	Sandy loam	1585	800-2000	21	0.28°42'N	34°45'0"E
KALRO-Alupe	Sandy loam	1189	1500-1850	23	0.29°50'N	34°7'34"E
Sang'alo Institute	Sandy loam	1385	1200	22	0.56°95'N	34.60°08"E

Source Jaetzold, *et. al.*, (2005)

3.1.2 Plant Materials

Ten released soybean varieties whose characteristics are described in table 2 below were used in this study. The varieties used were released based on their adaptability to the study area under sole cropping system by Kenya Plant Health Inspectorate Services (KEPHIS). The maize variety used was H513 a well-adapted maize variety in the AEZs where the study was undertaken. The maize variety was obtained from Kenya Seed Company.

Table 3.2 Varieties of soybean used in the study.

Variety	Year of Release	Optimal production altitude (m.a.s.l)	Maturity period
Black hawk	2009	800- 1700	5- 6 Months
EAI 3600	2009	800- 1700	2- 4 Months
Gazelle	2009	1200- 2400	3-6 Months
Hill	2009	1200- 2400	5-6 Months
Nyala	2009	1200- 2400	3-5 Months
DPSB 8	2010	900- 2400	3- 4 Months
DPSB 19	2010	900- 2400	4- 5 Months
Kensoy 009	2013	1000-2000	4- 5 Months
SC SAGA	2014	1000- 1800	2.5-4.5 Months
Salama	2014	1000- 1500	2- 4 Months

KEPHIS (2017)

3.1.3 Research Design

The experiment was a split plot arrangement laid in a randomized complete block design with three replications in a fine tilth prepared field. The main plot treatments were two cropping system; (i) maize-soybean intercrop (ii) soybean sole crops. . The sub plot treatments were ten soybean varieties. In the intercrop five rows of maize wereplanted at a spacing of 90cm x 25cm per plot. Two rows of soybean were drilled between two rows of maize at a spacing of 30cm between soybean rows and 30cm between soybean and maize rows. Soybean intra row spacing was 10cm. Both maize and soybean were planted in 5 meter rows.

In sole crop six rows of soybean per plot were drilled at inter row spacing of 45cm and 10cm intra row spacing. Fertilizer application, weed, pest and disease control were done using recommended package for the region.

3.1.4 Data Collection

Data was collected on yield and yield components of soybean. Yield was determined from a net plot of four inner rows with a total area of 7.2m². Yield components data were recorded from five randomly selected plants from the net plot. The data collected was as follows:

The data on yield components and yield of soybean were collected as described below:

- 1. Days to 50% flowering:** The number of days to 50% flowering was recorded from the date of planting.

2. **First Pod height:** The height of first pod was recorded to the nearest centimeter (cm).
3. **Number of Branches:** The number of primary branches were counted and recorded.
4. **Number of Pods per Plant:** The total number of fully filled pods was counted at maturity.
5. **Leaf area:** This was calculated in cm² using Ritcher *et al.*, (2014) method.
6. **Number of leaves per plant:** The average number of leaves was recorded per plant.
7. **Number of seeds per pod:** The average number of seeds per pod was recorded.
8. **Days to Maturity:** The number of days to maturity after planting were recorded when the stem and leaves had dried.
9. **Height at Maturity:** Height was measured from the base to the tip of the main branch in cm.
10. **Test Seed Weight:** The sample weight of 100 seed weight was recorded in grams (gm).
11. **Total Dry Matter:** Sun dried above ground vegetative material plus seed yield was recorded in kilograms (kg).

12. Yield: Was determined from a net plot of four inner rows with a total area of 7.2m². The soybean beds were hand harvested when pods and the stem were dry. The soybean moisture was determined using a moisture meter. The grain yield was adjusted to 11% moisture content using the formula.

$$\text{Adjusted yield} = \frac{\text{measured yield} \times (100 - \text{sample moisture content})}{(100 - \text{Standardized moisture content})}$$

13 **Harvest Index:** Soybean harvest index was calculated as the ratio of seed yield to sun dried aboveground vegetative materials plus seed yield.

3.1.5 Data Analysis

All measured variables were statistical analyzed by performing ANOVA using SAS software version 9.1. Treatment means were separated using the Least Significance Difference (LSD) at $\alpha = 0.05$. Correlation coefficients and their significance were computed based on standard method while path coefficients were worked out by the methods used by Dewey & Lu (1959).

3.2. Soybean intercropped with Maize

3.2.1. The study sites and materials

The study was conducted from April to august 2015 at three sites KALRO Kakamega, KALRO Alupe and Sanga'lo institute of Science and technology described in table 3.1. The ten soybean varieties and 1 maize variety used in the intercropped are described in table 3.2 and section 3.1.2.

3.2.2. Research Methodology

The experiment was laid in a completely randomized block design with 3 replication in every site of KALRO Kakamega, KALRO Alupe and Sang'alo institute. The maize variety HB 513 was planted in 5 rows of 5 meters spaced at 90cm inter row and 25cm intra row. The ten soybean varieties were randomly intercropped in between the maize rows in every plot with two rows falling between maize rows paced at 30cm inter row and 10 cm intra row in each site.

3.4 Data Collection

The data on yield components and yield of soybean were collected as described below Date of planting was recorded.

- 1. Days to 50% flowering:** The number of days to 50% flowering was recorded from the date of planting.
- 2. First Pod height:** The height of first pod was recorded to the nearest centimeter (cm).
- 3. Number of Branches:** The number of primary branches were counted and recorded.
- 4. Number of Pods per Plant:** The total number of fully filled pods was counted at maturity.
- 5. Leaf area:** This was calculated in cm^2 using Ritcher *et al.*, (2014) method.

6. **Number of leaves per plant:** The average number of leaves was recorded per plant.
7. **Number of seeds per pod:** The average number of seeds per pod was recorded.
8. **Days to Maturity:** The number of days to maturity after planting were recorded when the stem and leaves had dried.
9. **Height at Maturity:** Height was measured from the base to the tip of the main branch in cm.
10. **Test Seed Weight:** The sample weight of 100 seed weight was recorded in grams (gm).
11. **Total Dry Matter:** Sun dried above ground vegetative material plus seed yield was recorded in kilograms (kg).
12. **Yield:** Was determined from a net plot of four inner rows with a total area of 7.2m². The soybean beds were hand harvested when pods and the stem were dry. The soybean moisture was determined using a moisture meter. The grain yield was adjusted to 11% moisture content using the formula.

$$\text{Adjusted yield} = \frac{\text{measured yield} \times (100 - \text{sample moisture content})}{(100 - \text{Standardized moisture content})}$$

- 13 **Harvest Index:** Soybean harvest index was calculated as the ratio of seed yield to sun dried aboveground vegetative materials plus seed yield.

3.2.3 Data Analysis

All measured variables were statistical analyzed by performing ANOVA using SAS software version 9.1. (REFS). Treatment means were separated using the Least Significance Difference (LSD) at $\alpha = 0.05$.

3.3 Stability analysis of soybean in sole cropping and intercropping.

3.3.1. Materialand Method

The study was conducted from April to august 2015 at three sites KALRO Kakamega, KALRO Alupe and Sanga'lo institute) described in 3.1.1. The ten soya bean varieties and 1 maize variety used in the intercropped are described in table 3.1 in section 3.1.2. The experiment was a split plot arrangement laid in a randomized complete block design with three replications in a fine tilith prepared field. The main plot treatments were two cropping system; (i) maize-soybean intercrop (ii) soybean sole crop. The sub plot treatments were ten soybean varieties. Spacing in intercrop and sole crop management of the crop were as described in section 3.1.3

3.3.2 Data collection

Yield: Was determined from a net plot of four inner rows with a total area of 7.2m². The soybean beds were hand harvested when pods and the stem were dry. The soybean moisture was determined using a moisture meter. The grain yield was adjusted to 11% moisture content using the formula.

$$\text{Adjusted yield} = \frac{\text{measured yield} \times (100 - \text{sample moisture content})}{(100 - \text{Standardized moisture content})}$$

3.3.3. Data Analysis

Each cropping system at the three sites was considered as independent environment. To identify the genotype and environment interaction from combined analysis of variance was done. Where genotype and environment interaction variance was found to be significant, Eberhart and Russell (1966) joint linear regression analysis was used to estimate stability.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 ALUPE

4.1.1 Genetic variability of soybean under intercropping system

The agronomic characteristics of the soybean varieties differed significantly ($P \leq 0.05$) in Alupe except on the number of branches per plant on the intercropping system (Table 4.1). Blackhawk was the earliest variety to attain 50% flowering and mature under the intercropping system at 42.67 and 88.67 days respectively. Significant differences were observed among the varieties on the grain weight, harvest index and leaf area. Under the intercrops, Kensoy009 had the highest grain weight with 57.4g/m². Hill recorded the highest harvest index of 20.56% while the highest leaf area was recorded in Blackhawk with 94.06 cm² (Table 4.1).

Table 4.1. Mean Values of Branch number (BN), Days to flowering (DTF), Days to maturity (DTM), Grain weight (GTW), Harvest index (HI) and Leaf area (LA) for varieties under intercropping system at Alupe.

VARIETY	BN	DTF	DTM	GWT	HI	LA
HILL	2.67a	44.67a	89.00g	45.6bc	20.56a	89.49a
SC SAGA	2.00a	46.00b	97.00d	46.9abc	14.59ab	83.43a
EAI3600	2.67a	45.00c	93.44f	52.1ab	12.55b	65.94b
NYALA	2.00a	44.00d	96.00e	30.6de	13.74b	91.84a
BLACKHAWK	3.00a	42.67e	88.67g	44.1bc	15.87ab	94.06a
KENSOY009	2.67a	45.00c	100.33b	57.4a	19.86a	84.78a
SALAMA	2.00a	44.33cd	100.00b	19.7e	6.01c	87.13a
GAZELLE	3.00a	43.00e	98.00c	31.5d	9.87bc	82.29ab
DPSB19	2.00a	46.00b	94.33f	45.1bc	19.91a	81.88ab
DPSB8	2.00a	53.33a	108.33a	37.6cd	15.27ab	79.80ab
LSD	1.24	0.93	0.98	11.63	6.07	17.36
C.V	30.11	1.19	0.59	16.52	23.85	12.04

Treatment means with different letter(s) in the same column are significantly different at 5% probability

Blackhawk had the highest number of leaves of 17.33 that was significantly different ($P<0.05$) from SC Saga, Nyala, Kensoy009, Salama, Gazelle and DPSB19. EAI3600 recorded the highest dry matter yield of 3.0kg while DPSB8 was the tallest variety at 73.33cm. Nyala had the highest first pod at 12.67cm that was significantly different ($P<0.05$) from EAI3600, SC Saga and Hill with the highest number of pods per plant was 22 was recorded in DPSB8. SC Saga with 3 seeds per pod recorded the highest number of seeds per pod than other varieties. Salama had a significantly higher weight on 100 seeds than the other varieties of 16.6g as shown on Table 4.2.

Table 4.2. Mean values of Leaf number (LN), Dry matter (DM), Plant height (PH), First pod height (PDH), Pod per plant (PPP), Seeds per pod (SPP) and 100-seed weight (100-SW) for varieties under intercrop in Alupe.

VARIETY	LN	DM	PH	PDH	PPP	SPP	100-SW
HILL	15.33ab	1.70cd	45.33b	11.33ab	12.33de	2.00b	12.74b
SC SAGA	10.33c	2.30b	47.00b	10.33b	15.33cd	3.00a	12.42b
EAI3600	16.67a	3.00a	40.00b	9.33b	19.67ab	2.67ab	11.51b
NYALA	10.67c	1.60d	44.67b	12.67a	10.00e	2.33ab	16.54a
BLACKHAWK	17.33a	2.00bcd	44.67b	9.33b	15.00cd	2.67ab	12.00b
KENSOY009	9.00c	2.10bc	39.33b	11.33ab	14.00cde	2.67ab	15.99a
SALAMA	11.67bc	2.33b	39.67b	9.67ab	13.67cde	2.67ab	16.60a
GAZELLE	11.67bc	2.33b	43.33b	11.33ab	16.67bc	2.00b	16.20a
DPSB19	12.00bc	1.63cd	41.00b	10.83ab	12.33de	2.67ab	11.60b
DPSB8	13.00abc	1.80cd	73.33a	12.33ab	22.00a	2.67ab	16.52a
LSD	4.64	0.48	11.27	3.21	4.28	0.85	1.73
C.V	21.18	13.53	14.33	17.27	16.53	19.52	7.08

Means with different letter(s) in the same column are significantly different at 5% probability

4.1.2 Genetic variability of soybean under sole cropping

The varieties recorded significant differences in all characters under study in the sole cropping system as shown in Tables 4.3 and 4.4. Hill recorded the highest number of branches per plant with 4.67 branches. DPSB8 was the latest variety to achieve 50%

flowering and mature at 51.67 and 106 days respectively. Similarly DPSB8 recorded the highest grain weight of 91.5g/m². The highest harvest index of 23.19% was recorded in Blackhawk. Gazelle was superior to all other varieties on the sole cropping system on the number of leaves per plant with 90.16cm² as indicated in Table 4.3.

Table 4.3. Mean values of Branch number (BN), Days to flowering (DTF), Days to maturity (DTM), Grain weight (GTW), Harvest index (HI) and Leaf area (LA) for varieties under the sole cropping system at Alupe

VARIETY	BN	DTF	DTM	GTW	HI	LA
HILL	4.67a	44.00cd	88.00e	71.1abcd	19.49abcd	72.86ab
SC SAGA	4.33ab	43.67cd	96.67c	45.3d	11.00f	67.96b
EAI3600	3.33bcd	45.00c	95.00d	57.2bcd	17.68bcde	72.73ab
NYALA	3.67abc	42.33de	94.00d	44.7d	14.23def	90.16a
BLACKHAWK	2.33de	39.67f	86.33f	83.6ab	23.19a	81.95ab
KENSOY009	2.67cde	42.67d	98.33b	69.9abcd	15.62cdef	88.01a
SALAMA	3.33bcd	43.00d	97.00c	75.3abc	18.68abcde	90.16a
GAZELLE	2.00e	40.67ef	98.67b	90.0a	19.95abc	76.37ab
DPSB19	2.67cde	48.67b	95.00d	48.9cd	13.43ef	87.54a
DPSB8	2.00e	51.67a	106.00a	91.5a	21.97ab	70.98ab
LSD	1.27	1.71	1.04	26.51	5.34	19.47
C.V	23.96	2.25	0.64	22.81	17.77	14.21

Means with different letter(s) in the same column are significantly different at 5% probability

Hill with 21 leaves had the highest number of leaves in the sole cropping system which was significantly different ($P < 0.05$) from the other varieties except SC Saga. The greatest total dry matter of 3.23kg was recorded in gazelle. DPSB was the tallest variety at 60.23cm and similarly had the highest number of pods per plant of 29.33. Nyala recorded the highest first pod height of 12.33 cm. The number of seeds per pod ranged from 2 to 3 with the highest recorded in Salama. Kensoy009 recorded the heaviest 100seed weight of 18.06g as indicated in Table 4.4.

Table 4.4. Mean values of Leaf number (LN), Dry matter (DM), Plant height (PH), First pod height (PDH), Pod per plant (PPP), Seeds per pod (SPP) and 100-seed weight (100-SW) in Alupe for sole crop

VARIETY	LN	DM	PH	PDH	PPP	SPP	100-SW
HILL	21.00a	2.70abcd	45.00bc	9.67abc	21.33bcd	2.67ab	12.61bc
SC SAGA	20.00a	2.97abc	42.33bc	7.33c	22.00bcd	2.00b	11.51c
EAI3600	17.00ab	2.70abcd	44.67bc	11.17ab	24.00bc	2.67ab	11.97c
NYALA	16.33ab	2.30d	59.00a	12.33a	18.00d	2.33ab	15.87ab
BLACKHAWK	12.33b	2.60bcd	42.33bc	9.00bc	26.00ab	2.33ab	13.27bc
KENSOY009	14.67b	3.20ab	51.33ab	10.0abc	17.67de	2.33ab	18.06a
SALAMA	14.67b	2.90abcd	43.33bc	7.67c	19.33cd	3.00a	14.34bc
GAZELLE	12.33b	3.23a	42.00bc	9.00bc	24.67ab	2.67ab	14.33bc
DPSB19	14.00b	2.57cd	38.67c	9.33bc	12.67e	2.00b	14.85abc
DPSB8	14.33b	3.00abc	60.33a	8.67bc	29.33a	2.67ab	16.08ab
LSD	4.67	0.62	9.65	2.99	5.27	0.83	3.68
C.V	17.38	12.89	11.99	18.5	14.29	19.58	15.03

Means with different letter(s) in the same column are significantly different at 5% probability

4.1.3 Comparison of cropping systems on soybean characters in Alupe

The intercrop was significantly different ($P < 0.05$) from the sole crop at Alupe for number of branches, dry matter, grain weight, leaf number, first pod height and number of pods per plant but non-significant ($P < 0.05$) for leaf area, harvest index, seeds per pod and 100-seed weight. The intercropping system was superior to the sole crop on days to 50% flowering, days to maturity this could be attributed less light penetration to the

lower canopy soybean leading to slower accumulation of photo assimilates hence delaying maturity (Ijoyah and Fanen, 2012). Similarly intercropping had a significantly higher first pod height that would be attributed to etiolation due to shading. Sole cropping was significantly superior on the number of branches per plant, dry matter, grain weight, number of leaves per plant and number of pods per plant. Similar results were reported by (Hang *et al.*1984). This could be attributed to higher amount of light intercepted by light that increased accumulation of photo assimilates. There were no significant differences between the cropping systems on the leaf area, harvest index, plant height, number of seeds per pod and 100-seed weight(Table4.5).The result of present investigation is in conformity with earlier investigations of Turk *et al.* (1980) who reported that individual seed weight is rarely affected by growth factors except in case of severe water stress and hot desiccating winds causing forced maturity.

Table 4.5. Comparison of the cropping systems on the agronomic variables in Alupe

	Sole Crop	Inter Crop	LSD
Branches	3.1a	2.4b	0.90
Dry Matter	2.81a	2.08b	0.36
Days to 50% Flowering	44.13b	45.4a	0.14
Days to Maturity	95.5b	96.6a	0.66
Grain Weight	67.8a	41.1b	10.32
Leaf Area	79.87a	84.06a	6.90
Harvest Index	17.52a	14.83a	6.32
Leaf Number	15.67a	12.76b	1.55
1st Pod Height	9.42b	10.85a	3.36
Plant Height	46.9a	45.83a	4.19
Pods Per Plant	21.5a	15.1b	3.23
Seeds per Pod	2.47a	2.53a	0.63
100-Seed Weight	14.29a	14.21a	0.87

Means with different letters in the same row are significantly different at 5% probability

4.1.4 Correlation in soybean under intercropping

Correlation coefficient of soybean yield and yield characters under intercropping are shown in Table 4.22. The harvest index and grain weight were significantly and highly positively correlated in the intercropping system. Setegn *et al* (2006) reported similar findings in Beans when intercropped with Maize. This indicates that most assimilates were translocated to the grains. Days to maturity was negatively correlated to grain yield. This indicates that early maturing varieties fill grains early before increased shading of the higher canopy intercrop in the later stages. There were also positive correlations that were significant between the 1st pod height and days to flowering, and 100-seed weight and days to maturity. Negative correlation was observed on the leaf area and the dry matter-0.68.

4.1.5 Correlation in soybean under sole cropping

Correlation coefficients in Alupe under sole cropping system are shown in Table 4.25. High positive and significant correlation was observed between harvest index and grain weight 0.89 and grain weight and pods per plant 0.66. Malik *et al* (2006) reported similar results. Harvest index was also positively and significantly correlated to pods per plant; 0.69 and seeds per pod; 0.65. Grain weight was negatively correlated to the number of leaves-0.52, number of branches -0.61 and first pod height-0.34.

4.1.6 Path analysis in soybean under inter cropping

Though correlation analysis indicates the association pattern of component traits with yield, they also represent the overall influence of a particular trait on yield rather than providing cause and effect relationship. The path coefficient analysis technique

facilitates the partitioning of genotypic correlation into direct and indirect contribution of various characters on yield. Such information would be of great value in enabling the breeder to specifically identify the important component traits of yield and utilize the genetic stock for improvement in a planned way. The number of branches per plant had the highest positive direct effect on the grain yield of soybean under intercrop in Alupe 0.47 (Table 4.29). The trait was followed by the plant height 0.34 and number of leaves per plant 0.28. Positive direct effect was also recorded in harvest index; 0.18 and pods per plant; 0.05. Setegn *et al* (2006) reported that harvest index had the highest direct effect on seed yield. 100-seed weight had the highest negative direct effect on the grain yield -0.54. Days to maturity 0.50 and leaf area 0.33 indirectly and positively affected grain yield through number branches. In addition, pods per plant 0.42, 100 seed weight 0.37 and number of branches 0.27 had a positive and indirect effect on grain yield through plant height.

4.1.7 Path analysis in soybean under sole cropping

Direct and indirect effects by the agronomic traits under sole cropping in Alupe on grain are shown in Table 4.30. Number of seeds per pod 0.68 indicated highest positive direct effect on grain yield of soybean in sole crop system. This was followed by 100 seed weight 0.47. Similar results were reported by (Oz. *et al* 2009). However, number of leaves had a negative direct effect on grain yield at -0.41. Seeds per pod 0.25 had a positive indirect effect on grain yield through 100 seed weight. Similarly, plant height had a positive indirect effect of 0.67 on grain yield through 100 seed weight.

4.2 SANG'ALO

4.2.1 Variability of soybean varieties under intercropping

The agronomic traits had significant differences ($P \leq 0.05$) among the varieties in the intercropping system as indicated on Table 4.6 and 4.7 below. Nyala, Hill, EAI3600 and Blackhawk varieties achieved 50% flowering the earliest under the intercropping system (Table 4.6). The highest number of branches was recorded in Gazelle with 4 branches. The total dry matter ranged from 1.30 – 4.33kg was recorded with the highest recorded in DPSP8 (Table 4.7). The highest grain yield, harvest index, harvest index and number of leaves was recorded DPSB19 with 76.6g/m², 31.93% and 15.33 respectively (Table 4.6). SC Saga had the highest leaf area of 118.28cm².

Table 4.6. Mean values of Branch number (BN), Days to flowering (DTF), Days to maturity (DTM), Grain weight (GTW), Harvest index (HI) and Leaf area (LA) for varieties under the intercropping cropping system in Sang'alo

VARIETY	BN	DTF	DTM	GWT	HI	LA
HILL	3.33abc	44.00f	89.33f	63.1ab	31.67a	84.30c
SC SAGA	3.67ab	46.00c	97.67cd	66.1ab	22.17c	118.28a
EAI3600	2.33d	44.00f	95.33e	75.7a	28.77b	71.79e
NYALA	3.33abc	44.00f	96.7de	57.9ab	26.60b	62.23f
BLACKHAWK	2.67cd	44.00f	89.33f	48.9b	29.27ab	79.32cd
KENSOY009	3.67ab	45.00d	100.0b	54.9ab	13.40d	95.74b
SALAMA	3.00bcd	44.33e	96.33bc	57.2ab	15.73d	82.02c
GAZELLE	4.00a	45.00d	99.67cd	64.2ab	41.07c	73.27de
DPSB19	3.00bcd	49.00b	95.67de	76.6a	31.93a	67.82ef
DPSB8	3.00bcd	53.00a	110.67a	45.1b	7.53e	69.37e
LSD	0.87	0.31	2.24	22.41	2.87	6.82
C.V	15.79	0.4	1.34	21.42	7.35	4.95

Means with different letter(s) in the same column are significantly different at 5% probability

DPSB8 recorded the highest total dry matter of 4.33kg, plant height 72.67cm first pod height 15cm, number of pods per plant 21.33 and seeds per pod 3.0. Gazelle had the highest 100-seed weight of 17.30g.

Table 4.7. Mean Values of Leaf number (LN), Dry matter (DM), Plant height (PH), First pod height (PDH), Pod per plant (PPP), Seeds per pod (SPP) and 100-seed weight (100-SW) at Sang'alo under intercrop

VARIETY	LN	DM	PH	PDH	PPP	SPP	100-SW
HILL	14.00ab	1.43ef	44.33d	13.5bc	9.33de	3.00a	12.57e
SC SAGA	12.33bc	2.17cde	46.33cd	12.50cd	9.67de	2.67ab	14.47cd
EAI3600	11.00c	1.90cdef	55.33b	14.67ab	14.00bc	3.00a	14.23d
NYALA	11.33c	1.57def	37.33e	14.33ab	10.00de	3.00a	15.73bc
BLACKHAWK	12.33bc	1.30f	40.33e	12.00d	13.33bc	3.00a	11.97e
KENSOY009	12.33bc	3.00b	45.00d	12.50cd	11.67cd	2.33bc	16.47ab
SALAMA	13.00bc	2.60bc	49.33c	12.67cd	7.67e	3.00a	17.23a
GAZELLE	11.67c	2.20cd	55.00b	13.50bc	14.67b	2.00c	17.30a
DPSB19	15.33a	1.93def	54.33b	12.83cd	14.33bc	3.00a	11.13e
DPSB8	11.00c	4.33a	72.67a	15.00a	21.33a	3.00a	12.27e
LSD	2.2	0.73	3.66	1.47	2.56	0.43	1.44
C.V	10.3	19.33	4.26	6.42	11.92	8.96	5.86

Means with different letters in the same column are significantly different at 5% probability

4.2.2 Variability of soybean varieties under sole cropping

Genetic variability of soybean under sole cropping system is recorded in Tables 4.8 and 4.9.

Hill, Blackhawk, Salama and EAI3600 attained 50% flowering the earliest at 44 days compared to the other varieties under the sole cropping system. Salama recorded the highest grain weight of 79.9g/m² while DBSB19 had the highest harvest index of 31.07%. Hill variety had the largest leaf area of 133.56cm² that was significantly different (P<0.05) from the others.

Table 4.8. Mean values of Branch number (BN), Days to flowering (DTF), Days to maturity (DTM), Grain weight (GTW), Harvest index (HI) and Leaf area (LA) for varieties under the sole cropping system in Sang'alo

VARIETY	BN	DTF	DTM	GWT	HI	LA
HILL	4.00a	44.00c	89.0e	72.2ab	30.33a	133.56a
SC SAGA	2.33cd	45.33c	97.67bc	68.8ab	19.57c	111.96b
EAI3600	3.00bc	44.00c	96.00cd	77.6ab	24.30b	62.51f
NYALA	3.00bc	44.33c	94.33d	72.3ab	28.07ab	65.40f
BLACKHAWK	2.67bcd	44.00c	89.00e	55.6ab	25.63b	67.01f
KENSOY009	3.00bc	44.67c	99.33b	72.6ab	16.93cd	82.76e
SALAMA	2.67bcd	44.00c	99.00b	79.9a	11.53e	98.01d

GAZELLE	2.00d	44.67c	99.33b	53.5ab	13.03de	66.88f
DPSB19	2.33cd	48.67b	95.33d	72.1ab	31.07a	107.04bc
DPSB8	3.33ab	51.67a	108.0a	51.8b	5.07f	102.94cd
LSD	0.93	2.73	1.89	16.5	4.31	5.1
C.V	19.09	3.5	1.14	14.52	12.23	5.46

Means with different letters in the same column are significantly different at 5% probability

DPSB8 was the tallest variety and had the highest number of pods per plant at 70.33cm and 31.67 respectively (Table 4.9). Salama had the greatest 1st pod height at 14.83cm. Most varieties had three seeds per pod and DPSB19 had the lowest seed per pod and Gazelle had the highest seed weight of 18.43g.

Table 4.9. Mean values of Leaf number (LN), Dry matter (DM), Plant height (PH), First pod height (PDH), Pod per plant (PPP), Seeds per pod (SPP) and 100-seed weight (100-SW) in Sang'alo under the sole

VARIETY	LN	DM	PH	PDH	PPP	SPP	100-SW
HILL	12.67a	1.70de	42.33cd	11.07cde	17.33bc	3.00a	13.40de
SC SAGA	11.00a	2.57cd	38.33de	11.33cde	16.33bc	2.33bc	16.10bc
EAI3600	12.67a	2.33cde	47.33d	10.00e	21.00bc	3.00a	14.50cd
NYALA	11.00a	1.87de	34.67e	10.53de	14.33c	3.00a	18.27a
BLACKHAWK	12.00a	1.57e	38.33de	10.00e	14.33c	2.67ab	13.70d
KENSOY009	12.00a	3.10c	45.00bc	13.00abc	14.33c	3.00a	17.07ab
SALAMA	12.67a	4.20d	42.67bcd	14.83a	18.33bc	3.00a	17.83ab
GAZELLE	11.67a	3.03c	42.00cd	11.33cde	20.00bc	3.00a	18.43a
DPSB19	11.67a	1.67e	46.00bc	12.00bcd	23.00b	2.00c	11.80e
DPSB8	11.33a	7.27a	70.33a	13.83ab	31.67a	2.67ab	11.90e
LSD	1.86	0.89	4.91	1.85	6.96	0.5	1.74
C.V	9.13	17.72	6.41	9.15	21.28	10.55	6.64

Means with different letters in the same column are significantly different at 5% probability

4.2.3 Comparison of cropping system in Sang'alo

The number of branches was superior under intercropping. This is in contrast to the report of Silwana and Lucas, (2002) who reported reduced vegetative growth of growth components. 1st pod height and plant height were greatest under the intercropping system this may be due etiolation. Dry matter, grain weight, leaf area, harvest index and number of pods were found to be significantly superior under sole cropping agreeing

with the results of Silwana and Lucas, (2002)(Table 4.10). These could be due to increased light penetration that would in turn increase photo assimilation. There were no significant differences between the cropping systems were observed on the days to 50% flowering, days to maturity, number of leaves per plant and number of seeds per pod.

Table 4.10. Comparison of the cropping systems on the agronomic variables in Sang’alo

	Sole Crop	Inter Crop	LSD
Branches	2.83b	3.2a	0.80
Dry Matter	2.92a	2.21b	0.08
Days to 50% Flowering	45.53a	45.83a	0.25
Days to Maturity	96.7a	97.37a	0.76
Grain Weight	69.25a	60.99b	7.97
Leaf Area	89.61a	80.41b	2.52
Harvest Index	20.56a	22.81b	1.18
Leaf Number	11.87a	12.41a	2.31
1st Pod Height	11.8b	13.35a	0.24
Plant Height	44.7b	50a	3.01
Pods Per Plant	19.07a	12.5b	1.15
Seeds per Pod	2.77a	2.8a	0.14
100-Seed Weight	15.3a	14.34a	1.46

Means with different letters in the same rows are significantly different at 5% probability

4.2.4 Correlation in soybean under intercropping

Grain weight was highly and positively correlated to harvest index and number of leaves were at 0.61 and 0.39 respectively. Azar *et al.*, (2013) reported similar results in Chick pea when intercropped with spring barley. However, grain yield was negatively correlated to days to maturity and total dry matter at -0.46 and -0.36 respectively. Short duration varieties may have achieved grain filling before extreme completion may have set in from the maize. Highly positive and significant correlation was observed between plant height and dry matter, plant height and days to 50% flowering, plant height and

days to maturity, number of pods per plant and days to maturity, days to maturity and dry matter, days to flowering and dry matter, days to 50% flowering and number of pods per plant, and plant height and number of pods per plant. Significant negative correlation was observed between the number of seeds per pod and number of branches, harvest index and dry matter, and the harvest index and number of days to maturity.

4.2.5 Correlation in soybean under sole cropping

The harvest index was positively correlated with grain weight (0.6155) number of pods per plant (0.39) total dry matter (0.37) and number of branches 0.25. These results are in agreement to Ghodrati *et al.*, (2013). Musaana and Nahdy (1998) studied 8 pigeon pea (*Cajanus cajan* L.) lines and reported that pods/plant, seeds/pod, 100seed weight and primary branch number were positive and significantly correlated with grain yield. The dry matter was positively correlated to the days to flowering, days to maturity, plant height, and pods per plant. Plant height was positively correlated to days to flowering, days to maturity, as dry matter and pods per plant. The first pod height was positively correlated to the days to flowering and maturity as well as the dry matter.

4.2.6 Path analysis in soybean under inter cropping

In Sang'alo the total dry matter yield had the highest direct effect on the grain yield (0.46). Harvest index had a direct effect of 0.19 while pods per plant had a direct effect of 0.18 (Table 4.31). Azar *et al.*, (2013) reported that number of pods had the highest direct effect on grain yield. Days to flowering had the highest indirect effect of 0.73. Pods per plant had a positive indirect effect on grain yield through harvest index.

4.2.7 Path analysis in soybean under sole cropping

The seeds per pod had the highest positive effect on the grain yield (0.55) of soybean under sole cropping this is in conformity with the results of Malik *et al.*, (2006) (Table 4.32). This was followed by the days to 50% flowering (0.41) that contrasts with Srinives *et al.*, (1986) and days to maturity (0.34) that conforms to the results of Sharma *et al.*, (1983). Similarly harvest index, leaf area had positive direct effects as shown in Table 4.32. However, total dry matter had a negative direct effect on grain yield of -0.20. These results are in agreement with those obtained by Peksen and Gulumser (2005), Cokkizgin (2007) who found negative direct effects of dry matter on the grain yield in beans.

4.3 KAKAMEGA

4.3.1 Variability of in soybean under intercropping system

All varieties had the same on the number of branches (Table 4.11). Salama was the earliest variety to attain 50% flowering at 44 days. Hill was the earliest variety to mature at 89.9 days. DPSB8 had the highest grain weight and leaf area of 91.7g/m² and 147.35cm² respectively. EAI3600 had the greatest harvest index of 29.76%.

Table 4.11. Mean values of Branch number (BN), Days to flowering (DTF), Days to maturity (DTM), Grain weight (GTW), Harvest index (HI) and Leaf area (LA) for varieties under the intercropping cropping system in Kakamega.

VARIETY	BN	DTF	DTM	GTW	HI	LA
HILL	2.67a	50.00d	89.33e	86.9a	26.36a	84.10b
SC SAGA	2.33a	50.00d	100.0bc	78.6ab	22.28abcd	107.65ab
EAI3600	2.67a	46.33e	97.00d	82.6ab	29.76a	125.15ab
NYALA	2.00a	44.67f	98.33cd	76.6ab	24.91ab	88.14b
BLACKHAWK	2.67a	46.67e	91.67e	48.2b	17.82bcde	112.36ab
KENSOY009	3.00a	52.67c	102.67b	74.5ab	17.00bcde	133.22ab
SALAMA	2.00a	44.00f	101.33b	53.3ab	15.03de	123.80ab
GAZELLE	2.00a	45.00f	100.0bc	71.4ab	16.81cde	104.29ab
DPSB19	2.00a	54.67b	97.67cd	74.1ab	23.12abc	100.25ab
DPSB8	2.00a	61.00a	116.67a	91.7a	11.89e	147.35a
LSD	1.04	1.95	2.72	41.13	7.95	58.46
C.V	25.95	1.41	1.59	32.49	22.61	30.26

Means with different letters in the same column are significantly different at 5% probability

Kensoy009 with 9 leaves recorded the highest number of leaves (Table 4.12). DPSB8 had the highest dry matter and plant height 4.0kg and 84.33cm respectively. Nyala had the most number of pods per plant (25) while Kenysooy009 had the heaviest 100-seed weight of 18.91g.

Table 4.12. Mean Values of Leaf number (LN), Dry matter (DM), Plant height (PH), First pod height (PDH), Pod per plant (PPP), Seeds per pod (SPP) and 100-seed weight (100-SW) at Kakamega under intercrop.

VARIETY	LN	DM	PH	PDH	PPP	SPP	100-SW
HILL	7.00ab	1.80bcde	47.33bc	15.00a	12.67ef	2.67ab	16.35abcd
SC SAGA	7.00ab	1.93bcde	52.33bc	11.67a	11.00f	2.67ab	13.25d
EAI3600	8.00ab	1.50e	48.00bc	16.33a	14.00def	2.67ab	13.69cd
NYALA	7.67ab	1.67de	42.33c	13.67a	25.00a	3.00a	17.33abc
BLACKHAWK	7.00ab	1.43e	52.00bc	12.33a	14.00def	3.00a	13.48d
KENSOY009	9.00a	2.37bc	55.33bc	16.00a	18.33bc	3.00a	18.91a
SALAMA	7.33ab	2.43b	6.33b	17.33a	15.33cde	2.00b	16.61abcd
GAZELLE	6.67ab	2.30bcd	51.00bc	11.33a	17.67cd	2.67ab	18.37ab
DPSB19	6.00b	1.7ced	43.33c	17.00a	24.00a	2.67ab	13.16d
DPSB8	7.33ab	4.0a	84.33a	16.33a	22.00ab	2.33ab	15.05bcd
LSD	2.43	0.67	13.47	6.01	3.75	0.8	3.77
C.V	19.39	18.49	14.64	23.82	12.57	17.53	14.06

Means with different letters in the same column are significantly different at 5% probability

4.3.2 Variability of soybean under sole cropping

There were significant differences between the varieties on all the agronomic traits at $P \leq 0.05$ except on the number of branches and seeds per pod. Salamawas the earliest variety to attain 50% flowering at 44days although Blackhawk was the earliest to mature and also did have the highest grain weight and harvest index at 91.33day, 188.7g/m² and 33.9 days respectively (Table 4.13). EAI3600 had the greatest leaf area and dry matter at 149.37cm² and 5.85kg respectively. Gazelle indicated the highest number of leaves per plant at 12.33 leaves. As observed on the intercrop, DPSB8 was the tallest plants and had the greatest 1st pod height 66.67cm and 14cm. EAI3600 had the heaviest 100seed weight of 19.8 g. the highest number of pods per plant was recorded in SC Saga with 44.67 pods.

Table 4.13. Mean values of Branch number (BN), Days to flowering (DTF), Days to maturity (DTM), Grain weight (GTW), Harvest index (HI) and Leaf area (LA) for varieties under the sole cropping system in Kakamega

VARIETY	BN	DTF	DTM	GTW	HI	LA
HILL	3.00a	46.00d	90.00d	185.7ab	26.93b	102.94ab
SC SAGA	2.33a	49.33b	98.33bc	199.0a	24.50bc	106.31ab
EAI3600	3.33a	46.33d	97.67bc	194.5ab	18.10d	149.37a
NYALA	2.67a	44.67de	97.33c	129.2b	26.06b	112.36ab
BLACKHAWK	2.33a	45.00de	91.33d	198.7a	33.90a	84.78b
KENSOY009	2.67a	48.33c	101.0b	198.5a	18.48cd	108.33ab
SALAMA	2.67a	44.00e	97.33c	155.1ab	17.66d	88.14b
GAZELLE	2.67a	44.67de	100.0bc	189.6ab	19.40cd	137.26ab
DPSB19	3.00a	5.33b	97.00c	147.5ab	22.50bcd	102.94ab
DPSB8	3.33a	56.33a	112.33a	185.6ab	26.15b	95.54b
LSD	1.03	1.73	3.6	67.63	6.27	53.41
C.V	21.52	2.12	2.13	22.11	15.64	28.62

Means with different letters in the same column are significantly different at 5% probability

Table 4.14. Mean Values of Leaf number (LN), Dry matter (DM), Plant height (PH), First pod height (PDH), Pod per plant (PPP), Seeds per pod (SPP) and 100-seed weight (100-SW) at Kakamega under sole crop.

VARIETY	LN	DM	PH	PDH	PPP	SPP	100-SW
HILL	12.00ab	3.73bc	39.33d	8.00b	25.33e	2.67a	18.95ab
SC SAGA	10.33bc	4.40abc	48.67ab	10.33ab	44.67a	2.67a	13.67c
EAI3600	11.00abc	5.87a	45.00ab	7.33b	30.67cde	2.33a	19.80a
NYALA	10.00c	3.03c	38.33b	11.33ab	26.33e	2.33a	14.93bc
BLACKHAWK	10.33bc	3.13c	39.33b	10.67ab	27.33de	3.00a	20.58a
KENSOY009	10.33bc	6.13a	51.67ab	8.67ab	30.67cde	2.67a	19.77a
SALAMA	10.67abc	4.70abc	44.33ab	8.67ab	30.33cde	3.00a	17.95abc
GAZELLE	12.33a	5.53ab	46.00ab	7.00b	32.67cd	2.67a	19.18ab
DPSB19	9.67c	3.57c	48.33ab	12.00ab	35.33bc	3.00a	13.39c
DPSB8	10.33bc	3.93bc	66.67a	14.00a	39.33ab	2.67a	14.90bc
LSD	1.9	1.9	24.3	5.85	5.52	0.8	4.67
C.V	10.35	25.2	30.28	34.82	9.97	17.17	15.71

Means with different letters in the same column are significantly different at 5% probability

4.3.3 Comparison of cropping systems in Kakamega

The first pod height and plant height were the only traits that indicate significant ($P < 0.05$) superior in the intercrop compared to the sole cropping system (Table 4.15).

The number of branches per plant, dry matter, grain weight and number of pods per plant were superior in the sole cropping system compared to the intercropping system.

This view supports Ijoyah *et al.*, (2013) who reported higher number of branches and pods per plant under sole cropping. Days to 50% flowering were significantly reduced under the sole cropping system. The intense overcrowding of the intercrops could have prompted competitive demands on available nutrients and moisture, thus prolonging days to attain 50 % flowering (Ijoyah and Fanen, 2012). Insignificant differences were observed on the days to maturity, leaf area, harvest index, number of leaves per plant, number of seeds per pod and the 100-seed weight were not significantly ($P < 0.05$) different in the cropping systems.

Table 4.15. Comparison of the cropping systems on the agronomic variables in Kakamega

	Sole Crop	Inter Crop	LSD
Branches	2.8a	2.33b	0.52
Dry Matter	4.4a	2.11b	1.58
Days to 50% Flowering	47.5b	49.5a	1.29
Days to Maturity	98.23a	99.47a	1.37
Grain Weight	178.3a	73.79b	38.64
Leaf Area	108.8a	112.63a	11.20
Harvest Index	23.37a	20.5a	3.72
Leaf Number	10.7a	7.3a	1.74
1st Pod Height	9.8b	14.7a	5.38
Plant Height	46.77b	53.63a	2.55
Pods Per Plant	32.27a	17.4b	3.28
Seeds per Pod	2.7a	2.7a	0.63
100-Seed Weight	17.3a	15.62a	1.53

Treatments with different letters in the same row are significantly different at 5% probability

4.3.4 Correlation in soybean under intercropping

The dry matter and the harvest index were also positively correlated with the grain weight at 0.335 and 0.31 respectively but were not significantly different ($P>0.05$). Highly positive and significant association was observed between the plant height and dry matter ($r=0.9319$), days to maturity and plant height ($r=0.8368$), plant height and the leaf area ($r=0.7506$). Such results indicated that the increase of one character will increase in the correlated character. Negative and significant correlation were recorded between grain yield and days to 50% flowering and days to maturity at 0.56 and 0.35 indicating that an increase in these characters may lead to reduction in yield due to increased competition as the two intercrops achieve maximum demand for resources at the same time. Osiru (1980), had characterized an ideal genotype for association cropping as one that matures early. Negative and significant correlation was observed between the harvest index and dry matter ($r=-0.749$), harvest index and days to maturity

($r=-0.648$), and leaf area and harvest index ($r=-0.599$) indicating that an increase in vegetative matter reduces harvest index.

4.3.5 Correlation in soybean under sole cropping

In Kakamega, the 100-seed mass was positively correlated to the grain weight ($r=0.51$) this is in agreement with Rajkumar *et al.*, (2010). Dry matter and the grain weight also indicated a positive correlation ($r=0.4861$). Okonkwo and Idahosa, (2013) reported positive correlation between dry matter and grain weight. Highly positive and significant correlation were observed between the plant height and days to flowering ($r=0.9034$), days to flowering and days to maturity ($r=0.7527$), plant height and days to maturity ($r=0.9032$), 1st pod height and days to flowering ($r=0.7104$), and pods per plant and days to flowering ($r=0.6786$). Days to flowering is positively correlated with days to maturity (Cerna and Beaver, 1990). Negative correlation were observed on the harvest index and dry matter ($r=-0.811$), number of seeds per pod and leaf area ($r=-0.701$), 100-seed weight and 1st pod height ($r=-0.698$), and 100-seed weight and the number of pods per plant ($r=-0.633$) (Table 4.26).

4.3.6 Path analysis in soybean under inter cropping

In Kakamega, the number of seeds per pod, branch and number days to 50% flowering had high positive and direct effects on the yield (Table 4.33). Days to maturity had a high indirect effect on grain yield at -0.34 . Harvest index had a low direct effect on yield at -0.07 . Researchers have shown that, the biological yield and harvest index affect the grain yield of soybean (Shrivastava *et al.* 2001 and Cousin *et al.* 1985).

4.3.7 Path analysis in soybean under sole cropping

In the sole cropping, the days to 50% flowering had the greatest direct influence on the grain yield of 0.61 (Table 4.34). This is in conformity with the results of Waheed *et al.*, (2014). The number of seeds per pod (0.51) and number of branches at (0.3) had high direct effects on grain yield. These traits should be considered to improve grain yield in soybean under sole cropping. Similarly, number of leaves had a direct effect on grain yield at 0.25 as indicated in Table 4.34. Negative effects on grain yield were recorded by 1st pod height and total dry matter at -0.33 and -0.23 respectively.

4.4 Comparison of soybean in cropping systems in combined environments

4.4.1 Variability of soybean under intercropping system across sites

In the combined sites, Kensoy009 had the highest number of branches per plant and 100 seed weight under the intercropping system. Nyala and Blackhawk attained 50% flowering and matured earlier than others. Blackhawk had the highest number of seeds per pod (2.89). EAI3600 recorded the highest grain yield of 70.12g/m². Variety Hill had the harvest index of 26.20%.

Table 4.16. Mean values of Branch number (BN), Days to flowering (DTF), Days to maturity (DTM), Grain weight (GTW), Harvest index (HI) and Leaf area (LA) for varieties under the intercropping cropping system across sites

VARIETY	BN	DM	DTF	DTM	GWT	HI	LA
HILL	2.89ab	1.64b	46.22cd	89.22f	65.22a	26.20a	85.97a
SC SAGA	2.67ab	2.13b	47.33bcd	98.22cd	63.87ab	19.68abc	103.12a
EAI3600	2.56ab	2.13b	455.11cd	95.56e	70.12a	23.69ab	87.63a
NYALA	2.44ab	1.61b	44.22d	97.00de	55.06abc	21.75ab	80.74a
BLACKHAWK	2.78ab	1.54b	44.44cd	89.89f	47.09bc	20.99ab	95.25a
KENSOY009	3.11a	2.49ab	47.56bc	101.0b	62.25ab	16.75bc	104.58a
SALAMA	2.33b	2.46ab	44.22d	100.22b	43.40c	12.26c	97.65a
GAZELLE	3.00ab	2.28b	44.33cd	99.22bc	55.69abc	15.92bc	86.62a
DPSB19	2.33b	1.69b	49.89b	95.89e	65.27a	24.99a	83.32a
DPSB8	2.33b	3.38a	55.78a	111.89a	58.13abc	11.56c	98.89a
LSD	0.72	0.98	3.23	1.97	17.32	8.12	27.37
C.V	23.36	17.59	1.11	1.23	27.72	18.07	22.36

Means with different letters in the same column are significantly different at 5% probability

There were no significant differences ($P>0.05$) on the number of leaves and leaf area between the varieties in the intercrops. DPSB8 did have the greatest dry matter (3.38), height (76.78), first pod height(4.56) and pods per plant.

Table 4.17. Mean Values of Leaf number (LN), Dry matter (DM), Plant height (PH), First pod height (PDH), Pod per plant (PPP), Seeds per pod (SPP) and 100-seed weight (100-SW) across sites under intercrop.

VARIETY	LN	PLH	PDH	PDP	SPD	SWT
HILL	12.11a	45.67b	13.28ab	11.44b	2.56ab	13.87cd
SC SAGA	9.89a	48.56b	11.50b	12.00b	2.78ab	13.38cd
EAI3600	11.89a	47.78b	13.44ab	15.89ab	2.78ab	13.14cd
NYALA	9.89a	41.44b	13.56ab	15.00b	2.78ab	16.53ab
BLACKHAWK	12.22a	45.67b	11.22b	14.11b	2.89a	12.48d
KENSOY009	10.11a	46.56b	13.28ab	14.67b	2.67ab	17.12a
SALAMA	10.67a	47.78b	13.22ab	12.22b	2.56ab	16.81a
GAZELLE	10.00a	49.78b	12.06ab	16.33ab	2.22b	17.29a
DPSB19	11.11a	46.22b	13.56ab	16.56ab	2.78ab	11.96d
DPSB8	10.44a	76.78a	14.56a	21.78a	2.67ab	14.61bc
LSD	3.37	9.4	2.53	6.01	0.57	2.03
C.V	17.64	12.12	18.1	14	15.7	10.03

Means with different letters in the same column are significantly different at 5% probability

4.4.2 Variability of soybean under sole cropping across sites

There was significant ($P < 0.05$) variability among the varieties for most traits except for grain yield, leaf area and 1st pod height (Table 4.18). Newly recommended improved varieties of soybean have a wide range of maturity and diverse morphology (Olufajo, 1992; Adeniyani, and Ayoola, (2006). On the sole crop, Blackhawk had the highest harvest index (22.57).

Table 4.18. Mean values of Branch number (BN), Days to flowering (DTF), Days to maturity (DTM), Grain weight (GTW), Harvest index (HI) and Leaf area (LA) for varieties under the sole cropping cropping system across sites

VARIETY	BN	DM	DTF	DTM	GWT	HI	LA
HILL	3.89a	2.71b	44.67cde	89.00f	109.68a	25.58ab	103.12a
SC SAGA	3.00ab	3.31ab	46.11c	97.56d	104.38a	18.36ab	95.41a
EAI3600	3.22ab	3.62ab	45.11cd	96.22de	109.76a	20.03ab	94.87a
NYALA	3.11ab	2.40b	43.78de	95.22e	82.08a	22.79ab	89.31a
BLACKHAWK	2.44b	2.43b	42.89e	88.89f	112.03a	27.57a	77.91a
KENSOY009	2.78b	4.14ab	45.22cd	99.56b	113.65a	17.01b	93.03a
SALAMA	2.89ab	3.93ab	43.67de	97.78cd	98.82a	15.96b	91.44a
GAZELLE	2.22b	3.93ab	43.33de	99.33bc	111.03a	17.46ab	93.50a
DPSB19	2.67b	2.60b	49.22b	95.78de	89.47a	22.33ab	99.18a
DPSB8	2.89ab	4.73a	53.22a	10.78a	109.65a	17.73	89.82a
LSD	1.01	1.86	2.16	1.75	31.85	10.35	37.36
C.V	21.79	21.81	2.69	1.46	24.08	15.28	20.85

Means with different letters in the same column are significantly different at 5% probability

DPSB8 did have the highest number of pods per plant in the sole crop. Salama did have the highest number of seeds per pod in the sole cropping systems and Kensoy009 had the most 100-seed weight in sole crop.

Table 4.19. Mean Values of Leaf number (LN), Dry matter (DM), Plant height (PH), First pod height (PDH), Pod per plant (PPP), Seeds per pod (SPP) and 100-seed weight (100-SW) across sites under sole cropping.

VARIETY	LN	PLH	PDH	PPP	SPP	100-SWT
HILL	15.22a	42.22b	9.61a	21.33c	2.78ab	14.99ab
SC SAGA	13.78ab	43.11b	9.67a	27.67ab	2.33b	13.76b
EAI3600	13.56ab	45.67b	9.50a	25.22bc	2.67ab	15.42ab
NYALA	12.44ab	44.00b	11.40a	19.56c	2.56ab	16.36ab
BLACKHAWK	11.56b	40.00b	9.89a	22.56bc	2.67ab	15.85ab
KENSOY009	12.33ab	49.33b	10.56a	20.89bc	2.67ab	18.30a
SALAMA	12.67ab	43.44b	10.39a	22.67bc	3.0a	16.71ab
GAZELLE	12.11b	43.33b	9.11a	25.78bc	2.78ab	17.32ab
DPSB19	11.78b	44.33b	11.11a	23.67bc	2.33b	13.35b
DPSB8	12.00b	65.78a	12.17a	33.44a	2.67ab	14.29ab
LSD	2.98	9.39	3.24	7.6	0.5	4.01
C.V	14.2	19.41	22.23	14.32	15.94	13.34

Means with different letters in the same column are significantly different at 5% probability

4.4.3 Comparison of cropping systems on soybean characters across sites

Comparisons between cropping system for the combined sites are recorded in Table 4.20. The 1st pod height and plant height were significantly ($P < 0.05$) greater under the intercropping system. The competition for light from the greater population of plants in intercropping might have induced taller soybean plants (Ijoyah *et al.*, 2013). The number of branches per plant, dry matter, grain weight, number of leaves per plant and number of seeds per pod were significantly higher ($P < 0.05$) under sole cropping system. Similarly, Silwana and Lucas (2002) who reported that intercropping reduced vegetative growth of component crops. Leaf area, harvest index, number of seeds per pod and 100-seed weight were not significantly different ($P > 0.05$) across cropping systems.

Table 4.20. Comparison of cropping system on soybean characteristics across sites

	Sole Crop	Inter Crop	LSD
Branches	2.91a	2.64b	0.25
Dry Matter	3.38a	2.14b	0.31
Days to Flowering	45.72b	46.91a	0.25
Days to Maturity	96.81b	97.81a	0.32
Grain Weight	104.12a	58.61b	7.73
Leaf Area	92.76a	92.37a	2.54
Harvest Index	20.48a	19.38a	1.41
Leaf Number	12.74a	10.83b	0.62
1st Pod Height	10.34b	12.97a	1.20
Plant Height	46.12b	49.82a	1.09
Pods Per Plant	24.28a	15b	0.90
Seeds per Pod	2.67a	2.64a	0.17
100-Seed Weight	15.63a	14.72a	0.35

Treatments with different letters in the same row are significantly different at 5% probability

4.4.4 Correlation in soybean under intercropping

On the combined environments for the intercrop, the first pod height, harvest index, days to flowering and leaf area was positively correlated to the grain weight. However, grain weight was negatively correlated with days to maturity. Positive and significant correlation was observed between days to flowering and dry matter, days to maturity and dry matter, plant height and dry matter, leaf area and days to flowering, number of leaves and number of branches, plant height and days to flowering, leaf area and 1st pod height, days to flowering and number of pods per plant, days to maturity and number of pods per plant, and the 100-seed mass and days to maturity. Negative and significant correlations were observed on the harvest index and dry matter, harvest index and days to maturity, and the 100-seed weight and the number of leaves.

This results are in close conformity to those of previous investigators who also found plant height, number of leaves per plant (Malik *et al.*, 2007), number of pods and seeds

(Khan *et al.*, 2000; Board *et al.*, 2002; Liu *et al.*, 2005; Arshad *et al.*, 2006) to be the most important plant traits contributing to improved economic yield in soybean crop and hence suggested that these traits should be given more importance while selecting superior soybean genotypes. Previous studies in different parts of the world suggested various plant traits which should be considered to be most important while selecting soybean genotypes for higher seed yield. Plant height at harvest, number of pods per plant, weight of 100 seeds and seed yield were used to assess the performance of improved varieties of soybean. Similarly it was reported by Jin *et al.* (2010) that the yield increase is correlated with increasing pod number, while seed size and seeds per pod does not change greatly over time. Khan *et al.* (2000) studied heritability and correlation among yield determining components of 86 genotypes in Pakistan and reported that seed yield had a significant positive relationship with all yield components except 1st pod height.

4.4.5 Correlation in soybean under sole cropping

Grain weight was positively and significantly ($P < 0.05$) correlated to total dry matter (0.5371), harvest index (0.4017), leaf area (0.503) and pods per plant (0.7497) and 100-seed weight (0.5514) which indicates that a variety that has a high ability to synthesis photo assimilates and convert those into grain will have greatest grain yield in the sole crop. However, grain yield was negatively correlated to number of leaves. Days to maturity was positively and significantly correlated to the dry matter and leaf area (Table 4.28). The plant height and the number of pods per plant were also positively and significantly correlated. Iqbal *et al.* (2003) studied the relationships between

characters of 10 soybean varieties and reported that the plant height, pods/plant and seeds/pod had a positive and significant correlation with grain yield. Negative and significant correlation was observed on the harvest index and dry matter.

Malik *et al.* (2007) assessed the correlation coefficient and undertook path analysis among 27 genotypes of soybean, and reported that the correlation coefficient for the bean yield was positive and significant with leaf area, first pod height, days to flowering, and days to maturity, plant height and number of branches per plant.

Welsh *et al.* (1995) reported that the days to maturity are positively correlated with dry seed yield. Number of pods per plant is positively correlated with plant height (Arya *et al.*, 1999). Seed yield is positively correlated with number of pods per plant and number of seeds per pod (Chand, 1999; Coimbra *et al.*, 1998).

Chand (1999) and Coimbra *et al.* (1998) found positive correlation of seed yield with 100-seed weight, but it is negatively correlated with seed size (White and Gonzales, 1990). According to Nienhuis and Singh (1986) seed yield was positively correlated with number of pods per plant, number of seeds per pod and all architectural traits except branches per plant. These results give a clear indication that the yield components are mutually very closely associated. Thus, they concluded that productivity was more dependent on the number of pods per plant than on the number of seeds per pod because the latter characteristic was quite stable in the climatic region (Vasic *et al.*, 1997).

	GWT	BN	DM	DTF	DTM	HI	LA	LN	PHT	PDH	PDP	SDP	SWT
GWT	1	0.0033	0.3516	0.5627	0.3477	0.3071	0.029	0.117	0.1941	0.166	0.1874	0.0084	0.0195
BN		1	0.3366	0.0179	0.4023	0.276	0.117	0.5954	-0.1863	0.01	-0.526	0.5103	0.0368
DM			1	0.6448	0.9076	0.749*	0.6752	0.1246	0.9319*	0.2723	0.2788	0.5323	0.2478
DTF				1	0.6087	0.3255	0.4547	0.0439	0.6049	0.3682	0.3306	0.1093	0.2218
DTM					1	0.648*	0.7506*	0.2091	0.8368*	0.2809	0.4265	0.4284	0.1333
HI						1	-0.594*	0.0214	-0.7533	0.0112	0.1747	0.3712	0.2978
LA							1	0.4681	0.7952*	0.4057	0.0126	0.3622	0.0205
LN								1	0.1584	0.2291	0.0651	0.2431	0.4695
PHT									1	0.2578	0.0704	0.5412	0.0266
PDH										1	0.3025	0.4664	0.0315
PDP											1	0.1127	0.2227
SDP												1	0.0784
SWT													1

Table 4.21. The phenotypic correlation coefficient among variables for soybean genotypes in Kakamega in intercrops
GWT-Grain weight, BN-Branch number, DM-Dry matter, DTF-Days to flowering, DTM-Days to maturity, HI-Harvest index, LA-Leaf area, LN-Leaf number, PHT-Plant height, PDH-Pod length, PDP-Pods per plant, SDP-Seeds per pod, SWT-100-Seed weight

Table 4.22. The phenotypic correlation coefficient for characters in Alupe in intercropping system

	GWT	BN	DM	DTF	DTM	HI	LA	LN	PLH	PDH	PDP	SPD	SWT
GWT	1	0.3324	0.1412	0.0531	-0.2589	0.7465*	0.3285	0.1599	-0.1147	0.1501	0.1514	0.2694	-0.5897
BN		1	0.3201	-0.52	-0.4685	0.0964	0.0074	0.4773	-0.3087	0.3011	0.1366	0.4543	-0.1995
DM			1	0.2094	0.0372	-0.5351	0.684*	0.2175	-0.311	0.659*	0.5074	0.2536	-0.1774
DTF				1	0.7264*	0.1684	0.3294	0.1026	0.8826*	0.4161	0.6109	0.3172	0.202
DTM					1	-0.2942	-0.293	0.5484	0.603	0.4341	0.5135	0.2685	0.6983*
HI						1	0.1428	0.0504	0.0761	0.2811	0.2171	0.0178	-0.4245
LA							1	0.1486	-0.0626	0.2281	0.671*	-0.23	0.2389
LN								1	0.0571	0.5018	0.3122	0.1345	-0.5842
PLH									1	0.4847	0.6071	0.0956	0.2837
PDH										1	0.1395	0.4169	0.5871
PDP											1	0.2482	0.0077
SDP												1	-0.2569
SWT													1

GWT-Grain weight, BN-Branch number, DM-Dry matter, DTF-Days to flowering, DTM-Days to maturity, HI-Harvest index, LA-Leaf area, LN-Leaf number, PHT-Plant height, PDH-Pod length, PDP-Pods per plant, SDP-Seeds per pod, SWT-100-Seed weight

Table 4.23. The phenotypic correlation coefficient for characters in Sang'alo in intercropping system

	GWT	BN	DM	DTF	DTM	HI	LA	LN	PHT	PDH	PDP	SDP	SWT
GWT	1	-0.0748	-0.4637	-0.2129	-0.3555	0.614*	-0.0001	0.3937	-0.0432	0.0267	0.2741	0.0267	-0.0557
BN		1	0.1324	-0.05	0.1967	-0.2745	0.4002	0.0392	-0.1589	-0.223	-0.1971	-0.783*	0.5043
DM			1	0.7138*	0.942*	-0.932*	0.0452	-0.3702	0.7503*	0.3588	0.5819	-0.1667	0.1483
DTF				1	0.7297*	-0.4805	-0.1787	0.0197	0.8157*	0.3535	0.7558*	0.14	-0.4665
DTM					1	-0.877*	-0.0887	-0.4397	0.7504*	0.4583	0.5976	-0.2129	0.2295
HI						1	-0.1673	0.455	-0.5156	-0.1636	-0.3795	0.3056	-0.4055
LA							1	0.093	-0.2587	-0.5695	-0.4061	-0.2965	0.1643
LN								1	-0.1993	-0.5336	-0.3898	0.1948	-0.3915
PHT									1	0.5438	0.8050*	-0.0137	-0.2144
PDH										1	0.5265	0.2116	-0.0495
PDP											1	-0.0534	-0.3858
SDP												1	-0.6008
SWT													1

GWT-Grain weight, BN-Branch number, DM-Dry matter, DTF-Days to flowering, DTM-Days to maturity, HI-Harvest index, LA-Leaf area, LN-Leaf number, PHT-Plant height, PDH-Pod length, PDP-Pods per plant, SDP-Seeds per pod, SWT-100-Seed weight

Table 4.24. The phenotypic correlation coefficient among different pairs of yield and yield contributing characters for different genotypes of soybean in combined environments in intercrops

	GWT	BN	DM	DTF	DTM	HI	LA	LN	PHT	PDH	PDP	SDP	SWT
GWT	1	0.066	0.0198	0.439	-0.1277	0.5726*	0.3741*	0.4538*	0.2515	0.5841*	0.1534	0.1985	0.0614
BN		1	0.0712	-0.2424	-0.1874	0.1958	-0.1993	0.4216*	-0.1532	-0.0137	0.4188*	-0.0385	-0.0004
DM			1	0.4365*	0.7196*	0.6757*	0.156	-0.0037	0.5741*	0.116	0.3519	-0.1629	0.1002
DTF				1	0.6599*	-0.1312	0.4145*	0.3828*	0.7231*	0.4953*	0.5476*	0.0719	-0.0152
DTM					1	0.5053*	0.3328	-0.3336	0.7540*	0.3591	0.4966*	-0.1218	0.3693*
HI						1	-0.1318	-0.032	-0.2645	0.2815	-0.2716	0.3539	-0.2653
LA							1	0.5332*	0.3584	0.4259*	0.1412	-0.2239	0.2574
LN								1	-0.2095	0.5646*	-0.2856	-0.0036	0.4148*
PHT									1	0.4496*	0.4229*	-0.0988	0.1044
PDH										1	0.253	-0.0177	0.2493
PDP											1	0	0.074
SDP												1	-0.2454
SWT													1

GWT-Grain weight, BN-Branch number, DM-Dry matter, DTF-Days to flowering, DTM-Days to maturity, HI-Harvest index, LA-Leaf area, LN-Leaf number, PHT-Plant height, PDH-Pod length, PDP-Pods per plant, SDP-Seeds per pod, SWT-100-Seed weight

Table 4.25. The phenotypic correlation coefficient among different pairs of yield and yield contributing characters for different genotypes of soybean in Alupe sole cropping system

	GWT	BN	DM	DTF	DTM	HI	LA	LN	PHT	PDH	PDP	SDP	SWT
GWT	1	-0.6119	0.5401	-0.0412	0.2134	0.8891*	-0.16	-0.5176	0.0964	-0.34	0.6617*	0.6116	0.2131
BN		1	-0.3433	-0.1406	-0.431	-0.485	-0.192	0.9318*	-0.1175	0.0685	-0.2886	-0.0907	-0.5167
DM			1	-0.0116	0.5744	0.1413	-0.301	-0.1827	-0.0797	-0.5442	0.3088	0.2463	0.2052
DTF				1	0.5782	-0.0672	-0.2534	0.0906	0.32	-0.0901	0.0271	-0.0489	0.1736
DTM					1	-0.0861	-0.1442	-0.2326	0.4595	-0.2124	0.1973	0.1665	0.4634
HI						1	-0.1391	-0.436	0.1107	-0.0904	0.6958*	0.6466*	0.0295
LA							1	-0.4626	0.0563	0.2903	-0.671	-0.0227	0.6
LN								1	0.0084	0.0418	-0.102	-0.104	-0.4988
PHT									1	0.4343	0.2563	0.1551	0.5903
PDH										1	-0.2109	-0.0383	0.2566
PDP											1	0.4148	-0.2547
SDP												1	0.0085
SWT													1

GWT-Grain weight, BN-Branch number, DM-Dry matter, DTF-Days to flowering, DTM-Days to maturity, HI-Harvest index, LA-Leaf area, LN-Leaf number, PHT-Plant height, PDH-Pod length, PDP-Pods per plant, SDP-Seeds per pod, SWT-100-Seed weight

Table 4.26. The phenotypic correlation coefficient variables for genotypes in Kakamega sole cropping system

	GWT	BN	DM	DTF	DTM	HI	LA	LN	PHT	PDH	PDP	SDP	SWT
GWT	1	-0.073	0.4861	0.1638	0.0536	0.0715	0.1677	0.3889	0.2474	-0.3253	0.2523	-0.0042	0.51
BN		1	0.1613	0.4746	0.4175	-0.2788	0.3529	0.1051	0.4485	0.1133	-0.0068	-0.3362	-0.0648
DM			1	-0.0779	0.2555	-0.811*	0.6091	0.3749	0.2342	-0.654*	0.1288	-0.2551	0.4498
DTF				1	0.7527*	0.1034	-0.1962	-0.3816	0.9032*	0.7104*	0.6786*	0.0332	-0.5429
DTM					1	-0.2718	0.0682	-0.2102	0.9201*	0.4768	0.5849	-0.1886	-0.3651
HI						1	-0.534	-0.1951	-0.1792	0.5092	-0.1276	0.1901	-0.0758
LA							1	0.4487	-0.0866	-0.5595	-0.0157	-0.701*	0.2107
LN								1	-0.2225	-0.729*	-0.2698	-0.1825	0.5505
PHT									1	0.5111	0.6796*	0.0346	-0.3503
PDH										1	0.3994	0.1918	-0.698*
PDP											1	0.0929	-0.633*
SDP												1	-0.0066
SWT													1

GWT-Grain weight, BN-Branch number, DM-Dry matter, DTF-Days to flowering, DTM-Days to maturity, HI-Harvest index, LA-Leaf area, LN-Leaf number, PHT-Plant height, PDH-Pod length, PDP-Pods per plant, SDP-Seeds per pod, SWT-100-Seed weight

Table 4.27. The phenotypic correlation coefficient among variables for soybean genotypes in Sang'alo sole cropping system

	GWT	BN	DM	DTF	DTM	HI	LA	LN	PHT	PDH	PDP	SDP	SWT
GWT	1	0.2525	-0.5392	0.3844	-0.3746	0.6155*	0.1283	0.2717	-0.3912	-0.2165	0.392	0.0297	0.0753
BN		1	0.1369	0.0335	-0.1583	0.157	0.3984	0.3643	0.2984	0.0339	0.0929	0.3973	-0.3537
DM			1	0.6645*	0.8927*	-0.891*	0.1363	-0.145	0.8471*	0.7279*	0.7361*	0.0919	-0.1223
DTF				1	0.6578*	-0.3725	0.3282	-0.4306	0.8318*	0.4224	0.8645*	-0.5533	-0.6219
DTM					1	0.86*	-0.0024	-0.328	0.739*	0.6711*	0.6865*	-0.0272	0.0498
HI						1	0.0645	0.1127	-0.5943	-0.691*	-0.4821	-0.2288	-0.2223
LA							1	0.0716	0.2231	0.3768	0.2345	-0.3776	-0.4489
LN								1	-0.0244	0.0915	-0.0929	0.4399	-0.0988
PHT									1	0.5007	0.9118*	-0.1117	-0.5606
PDH										1	0.4029	0.008	0.0565
PDP											1	-0.2787	-0.573
SDP												1	0.5674
SWT													1

GWT-Grain weight, BN-Branch number, DM-Dry matter, DTF-Days to flowering, DTM-Days to maturity, HI-Harvest index, LA-Leaf area, LN-Leaf number, PHT-Plant height, PDH-Pod length, PDP-Pods per plant, SDP-Seeds per pod, SWT-100-Seed weight

Table 4.28. The phenotypic correlation coefficient among characters for different genotypes of soybean in combined sole cropping system across sites

	GWT	BN	DM	DTF	DTM	HI	LA	LN	PHT	PDH	PDP	SDP	SWT
GWT	1	-0.1939	0.5371*	0.3469	0.1815	0.4007*	0.5167*	0.5303*	0.073	-0.2669	0.7497*	0.1724	0.5114*
BN		1	-0.0341	-0.0425	-0.1902	-0.1789	0.0467*	0.6258	0.1362	-0.0081	-0.1294	-0.0454	-0.3532
DM			1	0.3662	0.5505*	0.4489*	0.4790*	-0.2986	0.4700*	-0.0678	0.6210*	0.0843	0.3242
DTF				1	0.6752*	0.0476	0.2102	-0.3164	0.6119*	0.3236	0.5564*	-0.0354	-0.0903
DTM					1	0.3644*	0.1145	-0.2673	0.6964*	0.297	0.4525*	0.0498	0.0902
HI						1	0.1001*	-0.3665	-0.3199	-0.0702	0.1255	0.1619	0.0681
LA							1	0.3962*	0.0806	-0.0579	0.3614*	-0.16	0.2319
LN								1	0.0122	-0.2348	-0.3601	-0.2937	-0.3996
PHT									1	0.342	0.4874*	-0.0285	-0.1738
PDH										1	-0.0578	0.2034	-0.1961
PDP											1	0.0713	-0.0006
SDP												1	0.2938
SWT													1

GWT-Grain weight, BN-Branch number, DM-Dry matter, DTF-Days to flowering, DTM-Days to maturity, HI-Harvest index, LA-Leaf area, LN-Leaf number, PHT-Plant height, PDH-Pod length, PDP-Pods per plant, SDP-Seeds per pod, SWT-100-Seed weight

Table 4.29. Genotypic path coefficients showing direct (diagonal) and indirect genetic effects of 12 quantitative traits on grain yield in Alupe under intercropping system.

	100-SW	BN	DTF	DTM	DM	HI	LA	LN	PH	PPP	PDH	SPP
100-SW	0.25181	0.29458	0.08499	0.08924	0.2084	0.02057	0.29355	0.05488	0.49919	0.37935	0.32671	0.07136
BN	0.25173	0.46936	0.07479	0.50072	0.27478	0.10339	0.33452	0.18027	0.43316	0.08719	0.07508	0.02978
DTF	0.38594	0.39635	0.07897	0.07135	0.13924	0.00906	0.03087	0.01738	0.02716	0.52959	0.58343	0.12055
DTM	0.48706	0.10057	0.06007	0.12875	0.1093	0.02218	0.12552	0.00554	0.12023	-0.3864	0.65367	0.14546
DM	0.03997	0.02062	0.62931	0.05917	0.21995	0.06498	0.39633	0.26249	0.20617	0.08366	0.23171	0.44658
HI	0.19662	0.3753	0.46484	0.11084	0.12075	0.17535	0.23487	0.02764	0.13557	0.09406	0.07735	0.67552
LA	0.08902	0.18305	0.38486	0.19565	0.47869	0.44794	0.12641	0.04403	0.03511	0.14938	0.02163	0.01952
LN	0.26712	0.24713	0.13742	0.29629	0.42211	0.35163	0.05344	0.28483	0.53128	0.05343	0.15914	0.02635
PH	0.37252	0.27005	0.07201	0.21706	0.10677	0.02277	0.13726	0.5879	0.34018	0.4217	0.15494	0.07183
PPP	0.20684	0.38738	0.28442	0.23895	0.03795	0.39152	0.03269	0.62579	0.10333	0.04723	0.01123	0.05778
PDH	0.19731	0.06902	0.31948	0.33506	0.34096	0.58126	0.42741	0.20737	0.01161	0.03296	0.08999	0.02407
SPP	0.02126	0.20213	0.06624	0.59398	0.4882	0.33676	0.21301	0.11033	0.20919	0.29934	0.0393	0.54005

GWT-Grain weight, BN-Branch number, DM-Dry matter, DTF-Days to flowering, DTM-Days to maturity, HI-Harvest index, LA-Leaf area, LN-Leaf number, PH-Plant height, PDH-1st Pod length, PPP-Pods per plant, SPP-Seeds per pod, 100-SW-Seed weight.

Table 4.30. Genotypic path coefficients showing direct (diagonal) and indirect genetic effects of 12 quantitative traits on grain yield in Alupe under sole cropping system

	100-SW	BN	DTF	DTM	DM	HI	LA	LN	PH	PPP	PDH	SPP
100-SW	0.46982	0.46698	-	0.10083	0.29929	0.02713	0.23185	0.21657	0.67553	0.14419	0.13134	0.02274
BN	0.36691	-0.2686	0.19603	0.17362	0.36726	0.03297	0.29536	0.15518	0.01725	0.41408	0.52725	0.13616
DTF	0.08097	0.29537	0.02227	0.06597	0.14597	0.32652	0.50953	0.0213	0.03719	0.37864	0.12706	0.0151
DTM	0.27041	0.33439	0.41611	0.04565	0.13698	0.13531	0.28347	0.14895	0.33385	0.57609	0.2047	0.03493
DM	0.23952	0.00184	0.21925	0.40442	0.16971	0.13266	0.03164	0.07802	-0.0813	0.28475	0.23801	0.36663
HI	0.3848	0.37341	0.14011	0.18291	0.04513	0.10807	0.32756	0.17423	0.01917	0.31087	0.13152	0.60219
LA	0.00981	0.23458	0.48017	0.1576	0.45053	0.16031	0.15924	0.10202	0.58722	0.15357	0.06554	0.01759
LN	-0.3307	-0.2274	0.40269	0.13249	0.3277	-0.1699	0.12409	0.41164	0.04958	0.15564	0.68752	0.03895
PH	0.15984	0.21835	0.24817	0.58042	0.0174	0.47461	0.17604	0.42168	0.01023	0.07797	0.26828	0.09519
PPP	0.34062	0.17608	0.17735	0.08199	0.26879	0.54357	0.2824	0.54104	0.12541	0.01551	0.00534	0.09499
PDH	0.10213	0.12319	0.05293	0.38482	0.28943	0.40012	0.19349	0.00464	0.23159	0.07134	0.07738	0.03838
SPP	0.2514	0.29978	0.00449	0.46862	0.18384	0.31246	0.40724	0.46486	0.08199	0.30717	0.03335	0.67789

GWT-Grain weight, BN-Branch number, DM-Dry matter, DTF-Days to flowering, DTM-Days to maturity, HI-Harvest index, LA-Leaf area, LN-Leaf number, PH-Plant height, PDH-1st Pod length, PPP-Pods per plant, SPP-Seeds per pod, 100-SW-Seed weight

Table4.31. Genotypic path coefficients showing direct (diagonal) and indirect genetic effects of 12 quantitative traits on grain yield in Sang'alo under intercropping cropping system

	100-SW	BN	DTF	DTM	DM	HI	LA	LN	PH	PPP	PDH	SPP
100-SW	0.10683	-0.49112	-0.34526	-0.15455	0.03194	0.07492	0.01432	0.31438	-0.12751	0.32506	-0.18146	0.41537
BN	0.00754	0.03861	0.11053	0.25953	-0.50794	0.52965	-0.16756	0.0435	0.25656	0.03322	0.01597	0.04739
DTF	-0.37302	0.18903	-0.15248	0.12016	-0.07431	0.15782	-0.05234	-0.09597	-0.56188	-0.01147	-0.51499	0.27769
DTM	-0.42384	-0.15123	0.02898	-0.73218	0.03384	0.17181	-0.19177	0.09959	-0.45988	0.10926	0.60556	-0.34017
DM	-0.40434	-0.15285	0.10703	0.00133	0.45978	-0.01243	-0.17386	-0.44058	0.34294	-0.23697	0.24569	0.50303
HI	0.35649	0.29946	-0.10575	0.27769	-0.09447	0.19398	-0.02738	0.22246	-0.28595	-0.16821	0.45671	0.55381
LA	0.09693	-0.34769	0.37225	0.02639	0.52594	0.01624	-0.23321	0.16044	-0.07743	0.12752	0.08262	0.08253
LN	0.1764	0.14146	0.56212	0.0599	-0.19295	0.18666	0.31962	-0.07879	0.10829	0.26469	0.16725	0.01591
PH	-0.39698	0.1367	0.0931	0.18459	0.03375	0.02383	0.15488	0.69767	0.02755	-0.38443	-0.06248	-0.04305
PPP	-0.36208	0.1984	-0.05622	0.22407	-0.18719	-0.41436	0.05773	0.06801	0.20198	0.17875	0.10247	0.13253
PDH	-0.21909	0.2109	-0.49719	0.00123	-0.00489	0.44421	0.632	-0.24143	0.00123	-0.00593	-0.11947	0.00041
SPP	0.04434	0.42522	0.05916	-0.43404	0.29836	0.4657	-0.33354	0.20632	0.21518	0.30111	-0.01235	-0.18909

GWT-Grain weight, BN-Branch number, DM-Dry matter, DTF-Days to flowering, DTM-Days to maturity, HI-Harvest index, LA-Leaf area, LN-Leaf number, PH-Plant height, PDH-1st Pod length, PPP-Pods per plant, SPP-Seeds per pod, 100-SW-Seed weight

Table 4.32. Genotypic path coefficients showing direct (diagonal) and indirect genetic effects of 12 quantitative traits on grain yield in Sang'alo under sole cropping system

	100-SW	BN	DTF	DTM	DM	HI	LA	LN	PH	PPP	PDH	SPP
100-SW	0.17602	0.55285	0.09786	0.1251	0.24094	0.088	0.3055	0.07921	0.41375	0.16711	0.45748	0.00058
BN	0.04302	0.1231	0.43875	0.62349	0.17017	0.26134	0.02394	0.40653	0.12507	0.10038	0.17934	0.05067
DTF	0.35174	0.21258	0.47031	0.07647	0.09514	0.49854	0.24436	0.17381	0.64291	0.08126	0.02172	0.11894
DTM	0.38919	0.20665	0.02158	0.37832	0.03728	0.21155	0.12443	-0.2208	0.04458	0.61146	0.46811	0.18054
DM	0.41224	0.13828	0.12874	0.00083	0.13174	0.25084	0.17004	0.00831	0.03127	-0.5033	0.14992	0.65221
HI	0.34379	0.35494	0.00186	0.00765	0.07257	0.03403	0.06555	0.04687	0.05615	0.35204	0.176	0.66372
LA	0.10316	0.40193	0.23629	0.11832	0.64528	0.03597	0.16564	0.47673	0.19234	0.04435	0.08689	0.00337
LN	-0.0789	0.01334	0.56207	0.2267	0.48833	0.07197	0.06192	0.21805	0.2633	0.16128	0.02627	0.01917
PH	0.40524	0.13042	0.06212	0.16533	0.20049	0.0383	0.22343	-0.1096	0.13448	0.30706	0.6747	0.22157
PPP	0.34713	0.18583	0.02565	0.05249	0.26699	0.05371	0.83403	0.16379	0.03301	0.24782	0.06132	0.01866
PDH	0.29224	0.14642	0.29304	0.30237	0.33234	0.42743	0.11085	0.45842	0.43041	0.05563	0.06058	0.00034
SPP	0.03139	0.41162	0.29018	0.47982	0.05343	0.52193	0.06585	0.46537	0.03877	0.05342	-0.1018	0.18077

GWT-Grain weight, BN-Branch number, DM-Dry matter, DTF-Days to flowering, DTM-Days to maturity, HI-Harvest index, LA-Leaf area, LN-Leaf number, PH-Plant height, PDH-1st Pod length, PPP-Pods per plant, SPP-Seeds per pod, 100-SW-Seed weight

Table 4.33. Genotypic path coefficients showing direct (diagonal) and indirect genetic effects of 12 quantitative traits on grain yield in Kakamega under intercropping cropping system

	100-SW	BN	DTF	DTM	DM	HI	LA	LN	PH	PPP	PDH	SPP
100-SW	0.0859	-	-	0.61968	0.48778	0.01457	0.36803	-0.2954	-0.1488	0.00167	0.16972	0.08351
BN	-0.1236	0.48434	0.52776	0.13134	0.10942	0.53522	0.10566	0.25891	0.39534	0.18391	0.23935	0.02424
DTF	0.3558	0.16044	0.40827	-0.2488	0.13888	0.26552	0.0431	0.54998	-0.5507	-0.1633	0.04938	0.11577
DTM	0.4655	0.04302	0.05265	0.34294	0.03193	0.03423	0.11918	0.21617	0.20996	0.57271	0.56718	0.02147
DM	0.4501	0.11268	0.10228	0.16358	0.20461	0.20172	0.07837	0.30717	0.18569	0.20409	0.38547	0.59651
HI	-0.2988	0.29011	0.34404	0.11139	0.20165	0.07678	0.00308	0.17474	0.01436	0.07466	0.31096	-0.5104
LA	0.2723	0.31077	0.16977	0.12569	0.13992	0.4038	0.18571	0.22397	0.33605	0.17242	0.27981	0.03922
LN	0.0423	0.32224	0.46873	0.09355	0.40179	0.27207	0.40373	0.06025	0.40108	0.03461	0.17987	0.02405
PH	0.4306	0.21052	0.01493	0.06235	0.20858	0.21483	0.11639	0.04998	0.07341	0.67043	0.37802	0.2204
PPP	0.16461	0.41757	0.12606	0.28884	0.43664	0.16807	0.37942	0.33742	0.32931	0.06606	0.08568	0.07269
PDH	0.10945	0.36682	0.00184	0.13491	0.2814	0.12476	0.12888	0.27249	0.16923	0.13302	0.21602	0.0376
SPP	0.18957	0.16596	0.23885	0.49881	0.38685	-0.1014	0.57155	0.28648	-0.0867	0.05903	0.13095	0.5511

GWT-Grain weight, BN-Branch number, DM-Dry matter, DTF-Days to flowering, DTM-Days to maturity, HI-Harvest index, LA-Leaf area, LN-Leaf number, PH-Plant height, PDH-1st Pod length, PPP-Pods per plant, SPP-Seeds per pod, 100-SW-Seed weight

Table 4.34. Genotypic path coefficients showing direct (diagonal) and indirect genetic effects of 12 quantitative traits on grain yield in Kakamega under sole cropping system

	100-SW	BN	DTF	DTM	DM	HI	LA	LN	PH	PPP	PDH	SPP
100-SW	0.1644	0.35421	0.22229	0.31443	0.40365	0.15883	0.22541	0.04078	0.03367	0.20862	0.58634	0.00858
BN	0.31728	0.29692	0.20448	0.19737	0.03878	0.09597	0.61304	0.14903	0.08596	0.2335	0.03765	0.01063
DTF	0.42805	0.25022	0.61096	0.12094	0.10158	0.10155	0.06039	0.03003	0.53159	0.54667	0.32466	0.09112
DTM	0.44453	0.09665	0.00807	0.10278	0.00602	0.3917	0.18291	0.45066	0.17755	0.5485	0.14675	-0.0224
DM	0.20342	0.46814	-0.0207	0.32388	0.22671	0.03506	0.00259	0.1821	0.02988	0.09994	0.37328	0.65571
HI	0.14132	0.29397	0.51094	0.31871	0.27211	0.05768	0.13737	0.12126	0.06828	0.22913	0.01898	0.53007
LA	0.13211	0.26584	0.11277	0.49791	0.00242	0.43744	0.03441	0.46013	0.00398	0.00456	0.18999	0.04896
LN	0.08725	0.30901	0.00271	0.55526	0.173	0.48976	0.31153	0.25005	0.34744	0.04345	-0.0246	0.04758
PH	0.43491	0.04158	0.27704	0.16589	0.25354	0.03571	0.04104	0.30105	0.09672	0.31029	0.08452	0.00654
PPP	0.38934	0.17871	0.01369	-0.1501	0.10975	0.58205	0.02	0.3338	0.16165	0.02	0.33583	0.04594
PDH	0.13796	0.36709	0.16868	0.00817	0.48901	0.04497	0.43966	0.40125	0.05251	0.00455	0.32861	0.11335
SPP	0.11128	0.23757	0.37708	0.07302	0.58649	0.06405	0.46218	0.02668	0.26434	0.07724	0.08815	0.50842

GWT-Grain weight, BN-Branch number, DM-Dry matter, DTF-Days to flowering, DTM-Days to maturity, HI-Harvest index, LA-Leaf area, LN-Leaf number, PH-Plant height, PDH-1st Pod length, PPP-Pods per plant, SPP-Seeds per pod, 100-SW-Seed weight

4.4.6 Path analysis in soybean under inter cropping

For effective simultaneous improvement of the key traits in crop productivity it is necessary to determine the magnitude of associations between the traits. In this study, correlation coefficient analysis indicated the magnitude and direction (positive or negative) of the associations between the traits. Through path analysis, however, it was possible to partition and quantify the complex associations between the various traits and grain yield into direct and indirect effects on grain yield.

Scales for path coefficients have been suggested by Lenka and Mishra (1973) where 0.00-0.09 is negligible association effects, 0.01-0.19 is low, 0.20-0.29 is moderate, 0.30-0.99 is high and >1.0 is very high. In the combined environments under the intercrops the number of branches per plant had the greatest direct effect on the grain yield followed by the number of seeds per pod, and harvest index (Table 4.29). Days to maturity and leaf area indicated direct negative effects on the grain yield in the intercropping system. This relationship indicates that an early genotype usually has higher grain yield than a late genotype. All the other traits did directly influence the grain yield while indirect effects were also observed on the number of leaves per plant and dry matter yield. These results were confirmed by Khan *et al.*, (2000); Singh & Yadava (2000) and Shrivastava *et al.*, (2001) in soybean. It may be concluded from the present studies that number of branches appeared to be the highest contributor to the grain yield. Therefore, direct selection of this trait will lead to higher grain yield as had been shown by Peksen and Gulumser (2005), Sabokdast and Khyalparast (2008) and Atta *et al.*(2008), in various studies on legume crops. Selection

for increasing seed yield through these traits might be more successful. Faisal *et al.* (2007) stated that the days to flowering had the maximum direct contribution to soybean yield. In contrast, Arshad *et al.* (2006) reported that the days to flowering had a negative direct effect on grain yield of soybean. They also reported that the total pods/plant was the character that had the highest direct effect on grain yield. Guler *et al.* (2001) stated that the direct effects of the number of pods/plant and number of seeds/plant on seed yield/plant of chick pea were positive and significant

Table 4.35. Genotypic path coefficients showing direct (diagonal) and indirect genetic effects of 12 quantitative traits on grain yield in intercropping system across sites

	1	2	3	4	5	6	7	8	9	10	11	12
1	0.006	-0.115	-0.366	0.499	0.329	0.206	0.431	0.005	0.268	-0.153	0.230	-0.125
2	-0.107	0.550	0.421	0.507	-0.075	-0.409	0.290	0.164	-0.428	0.163	0.060	0.029
3	0.282	-0.033	0.257	-0.197	-0.185	-0.014	0.160	-0.071	-0.317	-0.712	0.248	-0.101
4	-0.368	-0.050	-0.314	-0.224	0.107	0.154	0.116	-0.063	-0.087	-0.004	-0.819	0.060
5	0.243	-0.259	0.037	-0.386	0.167	0.052	-0.479	0.206	0.133	0.083	0.190	-0.536
6	0.216	-0.291	-0.046	0.175	0.484	0.348	0.237	-0.027	0.032	0.105	-0.212	-0.655
7	-0.067	-0.063	-0.180	0.054	0.104	0.101	-0.128	0.371	0.323	0.019	-0.076	0.007
8	0.279	-0.369	0.156	0.112	-0.026	0.145	0.195	0.280	0.623	-0.283	-0.087	-0.020
9	0.038	0.173	-0.331	-0.366	-0.129	-0.180	-0.184	-0.184	0.215	0.526	0.314	0.108
10	0.078	0.224	-0.261	-0.115	-0.040	0.046	0.118	0.052	0.057	-0.110	0.038	0.019
11	-0.177	-0.056	-0.144	0.003	-0.172	-0.325	-0.073	0.219	0.037	-0.102	0.053	0.044
12	0.154	0.074	-0.132	-0.159	0.038	-0.199	0.065	-0.080	0.220	0.049	-0.008	0.488

1-100-Seed weight, 2-Branch number, 3-Days to flowering, 4-Days to maturity, 5-Dry matter, 6-Harvest index, 7-Leaf area, 8-Leaf number, 9-Plant height, 10-Pods per plant, 11-First Pod height, 12-Seeds per pod.

4.4.7 Path analysis in soybean under sole cropping

Indirect effects were observed where the number of pods per plant did positively and directly influence the dry matter which in turn had a direct and significant influence on the grain yield of soybean. Rasaily *et al.*, (1986) reported similar results for number of pods per plant, branches per plant and unfilled pod plant per plant in soybean. A path coefficient analysis of some yield component interactions in common bean revealed that number of pods per plant exerts a preponderant direct effect upon yield (Duarte and Adams, 1972). In divergent parents with respect to seed number per pod and seed weight, these components also assumed major roles in determining yield. Leaf number was highly associated with pod number per plant but leaf size was highly associated with seed size (Singh *et al.*, 1985).

Singh *et al.* (1985) conducted path coefficient study in pea for ten quantitative traits. They concluded number of pods per plant, number of seeds per pod, 100-seed weight and harvest index are the main yield components affecting yield directly. High indirect effects were contributed by number of branches, plant height and flowering via number of pods per plant; by pod length via 100-seed weight and by maturity via both the component traits. Protein content had negligible effect on seed yield. In parameters selection for yield improvement in French bean, (Babar *et al.*, 2002).

Table 4.36. Genotypic path coefficients showing direct (diagonal) and indirect genetic effects of 12 quantitative traits on grain yield in sole cropping system across sites

	1	2	3	4	5	6	7	8	9	10	11	12
1	0.371	-0.307	0.078	-0.526	0.291	0.270	0.495	0.096	0.126	0.060	0.389	-0.112
2	0.151	-0.328	0.348	0.316	0.435	0.387	0.089	-0.291	-0.339	-0.240	0.178	0.065
3	0.117	-0.121	0.272	0.256	-0.193	0.205	0.298	-0.422	0.043	0.603	0.004	0.009
4	-0.017	0.174	-0.480	0.145	-0.103	-0.187	0.206	-0.335	0.237	-0.669	-0.011	-0.033
5	-0.441	-0.262	-0.040	-0.074	0.116	0.116	-0.282	-0.029	-0.159	0.102	-0.467	-0.536
6	-0.169	-0.147	-0.228	0.296	0.626	0.163	0.280	0.096	0.023	-0.212	-0.140	-0.553
7	0.071	-0.130	0.069	0.011	-0.308	-0.247	0.070	-0.103	0.248	0.072	0.123	0.020
8	0.143	-0.538	0.138	0.078	0.237	0.340	0.179	0.120	0.707	0.147	-0.122	-0.139
9	0.101	-0.027	-0.135	-0.312	-0.129	-0.032	-0.121	-0.247	0.119	0.084	0.064	0.016
10	0.270	0.098	-0.191	-0.040	-0.538	-0.387	0.081	0.035	-0.084	-0.085	0.557	-0.073
11	0.012	-0.159	-0.195	0.010	0.246	0.289	0.021	0.274	-0.118	0.017	-0.438	0.060
12	-0.117	-0.069	0.177	-0.097	-0.045	-0.232	0.158	0.090	-0.118	0.024	-0.199	0.600

1-100-Seed weight, 2-Branch number, 3-Days to flowering, 4-Days to maturity, 5-Dry matter, 6-Harvest index, 7-Leaf area, 8-Leaf number, 9-Plant height, 10-Pods per plant, 11-First Pod height, 12-Seeds per pod,

4.5 Genotype × cropping system interaction for yield

4.5.1 Genotype × cropping system interaction for yield in Alupe

There was a genotype × cropping system interaction (Figure 4.1). Under the intercropping system, Kensoy009 had the highest grain yield in Alupe. Three varieties were superior in sole cropping system where DPSB8 and Gazelle had the highest seed yield and closely followed by Blackhawk as shown on the Figure 4.1 below.

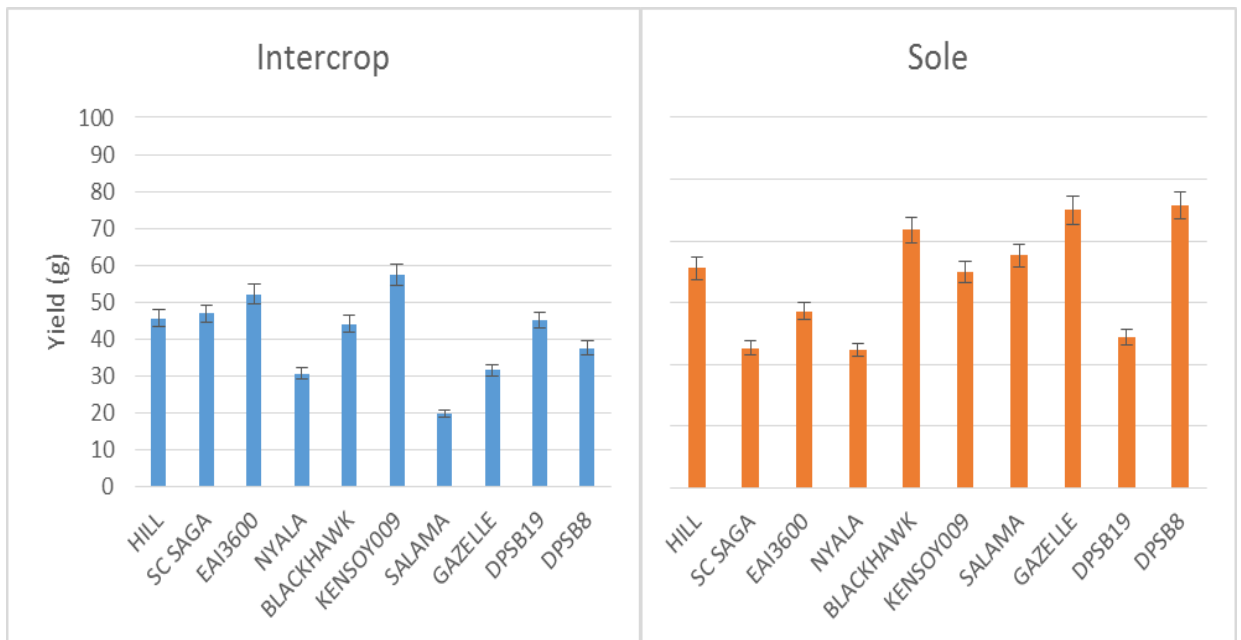


Figure 4.1. Grain yield in Alupe for the varieties in intercrops and sole crop system

4.5.2 Genotype × cropping system interaction for yield in Sang’alo

In Sang’alo significant interaction ($P < 0.05$) were observed between the cropping system and the varieties where EAI3600 and DPSB19 indicated highest yield in the intercropping system. On the other hand, EAI3600 and Salama had the greatest grain yield in the sole cropping system as shown below on Figure 2. The results on EAI3600 are in tandem to those by Clark and Shibles (1979), observed that a group of high yielding bean cultivars under monoculture maintained their yield superiority also under association cropping. They also reported a lower yield reduction for their high yielders a result of intercropping.

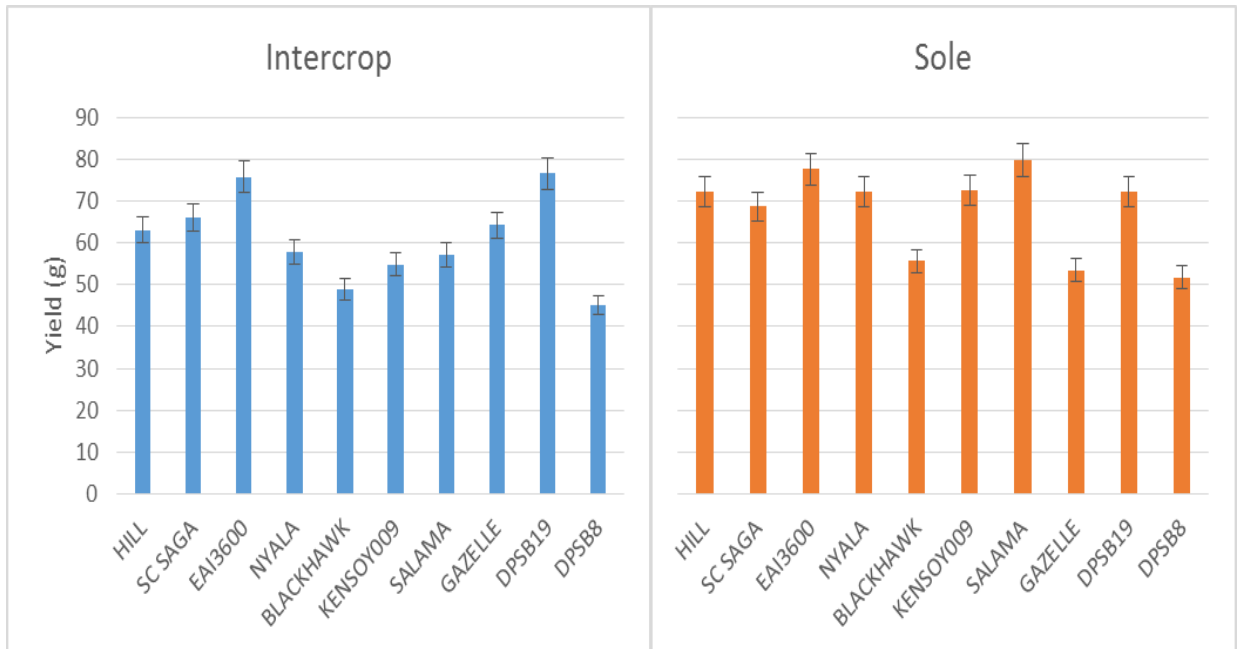


Figure 4.2. Grain yield in Sang'alo among the varieties of soybean in intercropping and sole system

4.5.3 Genotype × cropping system interaction for yield in Kakamega

DPSB8 had the highest grain yield in Kakamega under the intercropping system. All the varieties had significantly ($P < 0.05$) higher yield under pure stands than in intercropping system to the extent that the yield was doubled in some cases (Figure 4.3) where SC Saga, Blackhawk and Kensoy009 had the highest grain yield under sole cropping. Hill EAI3600 and DPSB8 had the highest grain yield under inter cropping.

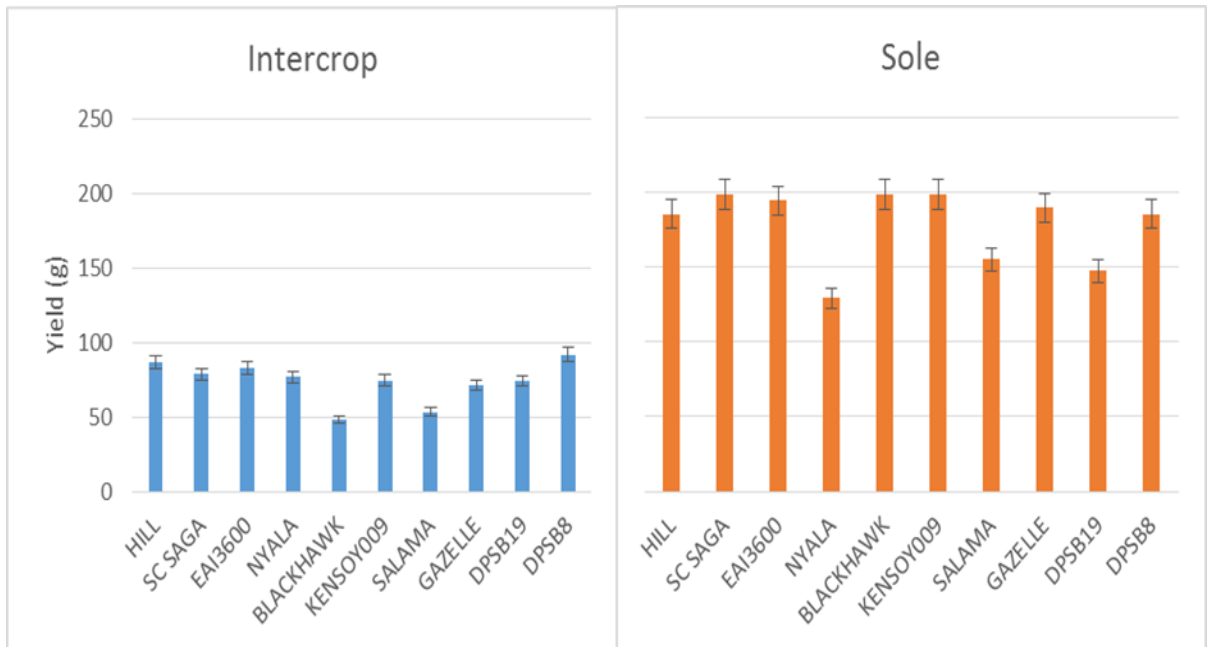


Figure 4.3. Grain yield in Kakamega for the varieties in intercropping and sole crop system

In all the sites, it was observed that the sole crop had a greater yield advantage than the soybean yield in intercrop. Across the environments, EAI3600 was the highest yielding variety in the intercropping system and was significantly different from the other (Figure 4.4). This could be attributed to early flowering and maturity that enables it to have grain filling before complete shading by the maize. Therefore, EAI3600 is recommended across the environments under intercropping. Breeders usually recommend a variety with good performance across environments for commercial release. Seed companies prefer varieties that can be adopted by many farmers in order to optimize profit due to economies of scale.

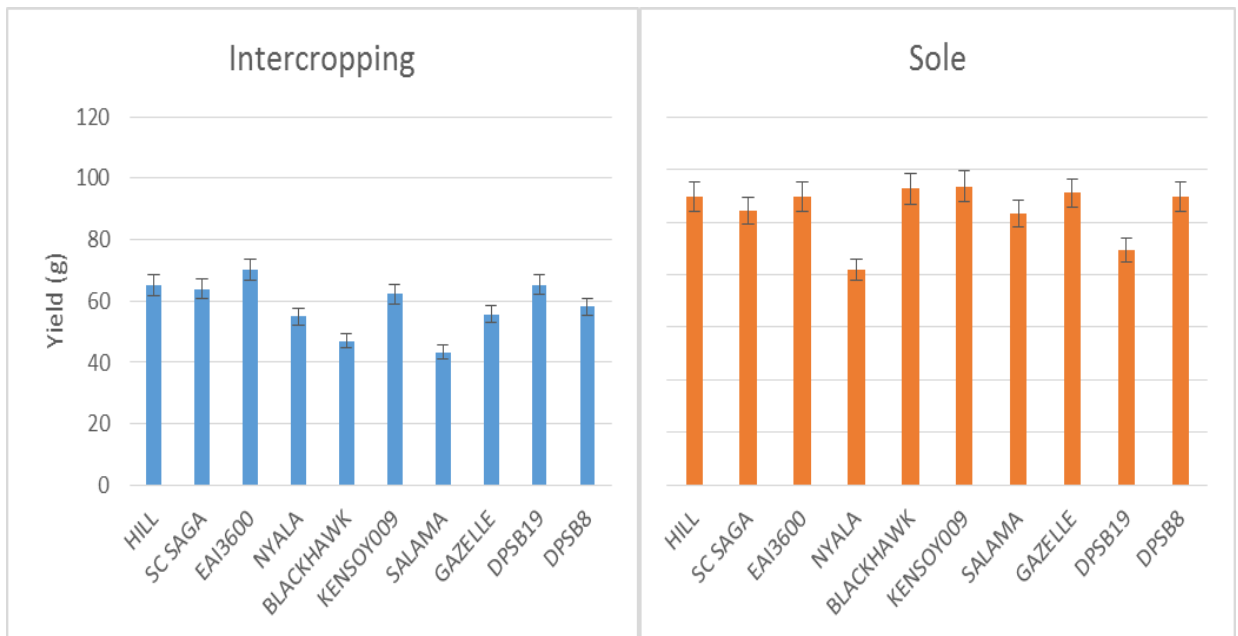


Figure 4.4. Seed yield in combined environments for the varieties in intercrops and sole crop

The reduction in seed yield potential under intercropping was mainly due to the effect of shading on photosynthetic activity of soybean plant. Similarly, Johnson *et al.* (1969) have also indicated reduced photosynthetic activity due to shading in soybean, canopy structure, radiation intensity, temperature, wind and CO₂ concentration around the individual plant influences various procedures involved in the photosynthesis, which in turn produce yield. Wahua and Miller (1978) showed that if soybean was intercropped with tall sorghum, due to shading and competition effects, nitrogen fixation by soybean was reduced mainly due to reduction in number of nodules per plant, weight per nodule, specific nodule activity. These results are in parallel with those obtained by Metwally *et al.* (2009) who indicated that good yielding ability of soybean cultivars under intercropping culture may be due to least effect of intercropping on individual plant characters.

4.6 Stability analysis

In the interaction between the genotypes and environment on the basis of yield, Kensoy009 was the most stable variety across all the environments followed closely by Hill in both sole and intercropping systems (Table 4.37). The first parameter was the mean of grain yield over the three sites. This column recorded that the variety Kensoy009 gave the highest yield of 76.58g/m^2 and was the most favorable across all the sites. Variety Nyala with yield of 59.99g/m^2 recorded poor yield over all the environments. On the basis of mean yield ranking, five genotypes; Kensoy009, Hill, SC Saga, Gazelle and DPSB8 were top yielding varieties across the three sites and both cropping systems. The stability of genotypes was found to have significant average responsiveness (b_i) and significant deviation from regression line (S^2_{di}). All varieties had insignificant deviation mean square from the regression co-efficient. This implies that all varieties were stable and predictable across the environments.

The estimates of b_i Table 4.37 were significantly different from unit. Hill, SC Saga Kensoy009, Gazelle DPSB8 and EAI3600 had significant b_i of more than unit. This indicates that they are adapted to high yielding environment especially in the sole cropping system. Nyala, Salama and DPSB19 had a significantly b_i of less than unit which indicates their adaption to poor yielding environment because their yields are hardly changing across the environment. However, their mean yields are less than the grand mean indicating that they are outperformed by varieties better adapted to high yielding environments in the poor environment.

Table 4.37. The yield stability estimates for the varieties

Variety	Mean(g/m ²)	bi	S ² di	Rank
HILL	76.09	1.02*	17.96	2
SC SAGA	72.56	1.59*	168.47	3
EAI3600	69.84	1.06*	107.67	6
NYALA	59.99	0.66*	182.13	10
BLACKHAWK	69.57	1.19*	288.7	7
KENSOY009	76.58	1.11*	88.28	1
SALAMA	62.43	0.89*	180.97	9
GAZELLE	72.48	1.11*	180.81	4
DPSB19	68.14	0.72*	147.39	8
DPSB8	72.33	1.08*	324.61	5
GRAND MEAN	70			

*significantly different from unit at P=0.05.

A scatter plot on Figure 4.5 showed that Alupe intercrop, Sang'alo sole, Kakamega intercrop were in one mega environment closely followed by Sang'alo intercrop and Kakamega sole while Alupe sole was greatly isolated with Kensoy009 and Hill being the most stable genotype between the sites while SC Saga and EAI3600 being ideal for Kakamega and Sang'alo.

Higher magnitude of mean squares due to environments indicates considerable differences between environments for all the characters and that these characters were greatly influenced by environments; thereby suggesting the large differences between environments along with greater part of genotypic response was a linear function of environments. These results are in agreement with the earlier findings of Dillion *et al.* (2009) and Jai Dev *et al* (2009).

Figure 4.6 shows an environmental focused ranking biplot where Kakamega sole is the most ideal environment followed by Alupe intercrop, then Kakamega intercrop, then

Alupe sole then least but not last Sang'alo intercrop and lastly Sang'alo sole site for the soybean varieties.

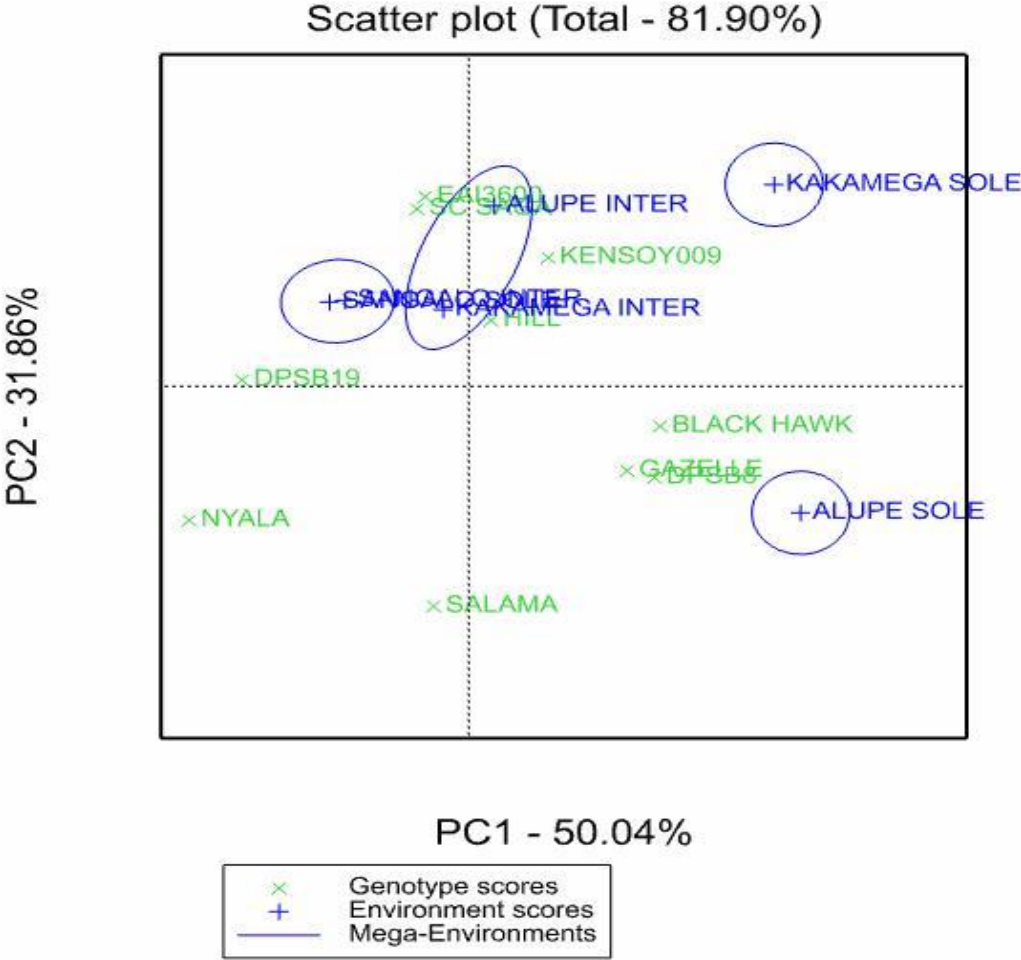


Figure 4.5 A scatter plot showing PC2 verses PC1 for 10 soybean genotypes and 6 environments

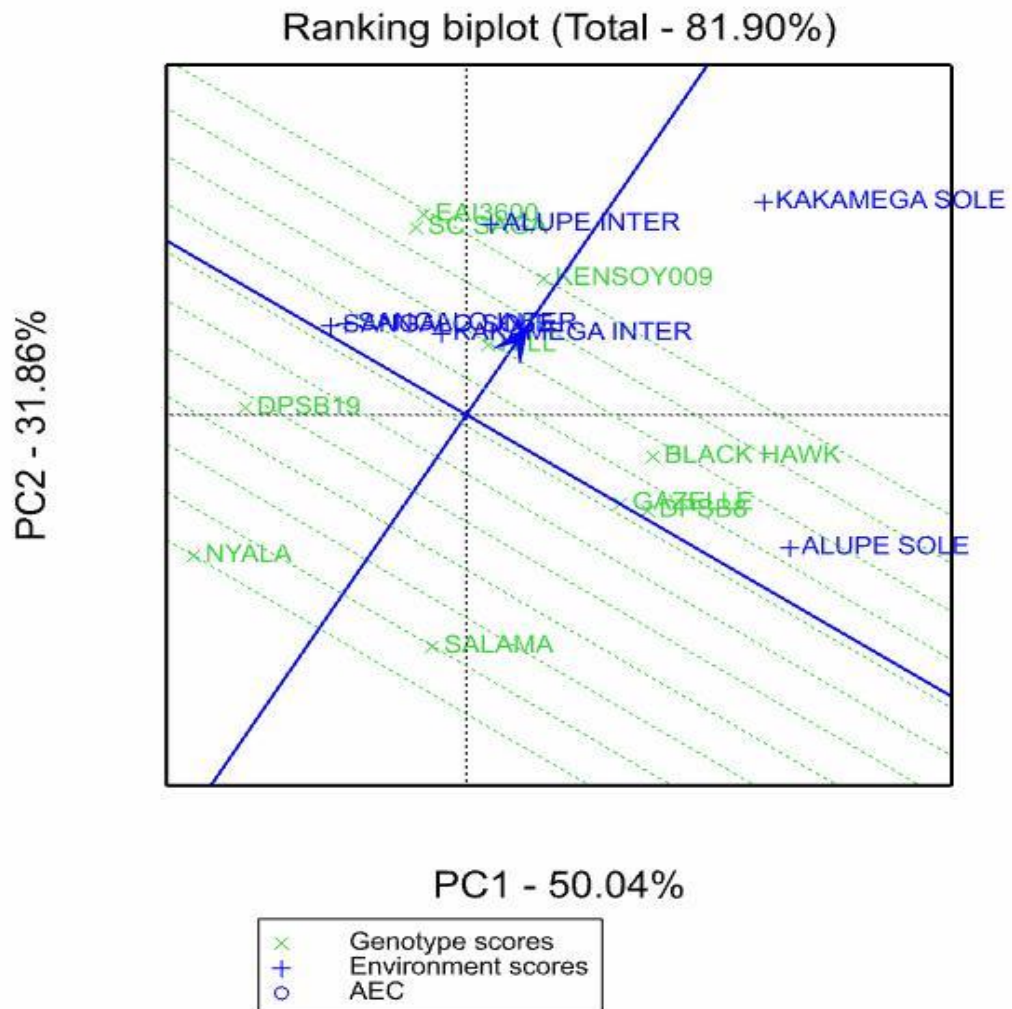


Figure 4.6. Environment focused ranking biplot showing PC2 verses PC1 for 10 soybean genotypes and 6 environments.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATION

5.1 CONCLUSION

- Cropping systems influenced various variables with yield and yield components being significantly higher ($P \leq 0.05$) in the sole crop than the intercrop. The 1st pod height, days to 50% flowering and maturity and plant height at maturity were significantly higher in intercrops.
- Comparison of varieties' yields between the cropping systems indicated that EAI3600 DPSB19 and Hill are the best yielding varieties in intercropping while Nyala and DPSB19 recorded significantly lower yields in the intercropping system.
- Stability analysis indicated that Hill, SC Saga, Kensoy009, Gazelle, DPSB8 and EAI3600 are adapted to high yielding environment.

5.2 RECOMMENDATIONS

- There is the need to evaluate soybean varieties in intercropping system for increased yields in intercropping system.
- The highest yielding varieties for intercropping were EAI3600 and DPSB19 and therefore are recommended for intercropping by farmers.
- Further research on soybean variety adaptation to intercropping using more genotypes and stability analysis should be conducted in more environments and seasons to get more reliable results.

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