PERFORMANCE OF SELECTED SOYBEAN CULTIVARS AS INFLUENCED BY DIFFERENT RATES OF SYMPAL FERTILIZERS IN BUNGOMA AND KAKAMEGA COUNTIES

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A THESIS SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENTS F0R THE DEGREE OF MASTER OF SCIENCE IN AGRONOMY, SCHOOL OF AGRICULTURE AND BIOTECHNOLOGY UNIVERSITY OF ELDORET, KENYA

2016

DECLARATION

Declaration by the Student

This thesis is my original work, and to the best of my knowledge, has not been presented in any University

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Declaration by the Supervisors

This thesis has been submitted for examination with our approval as the University Supervisors.

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DEDICATION

I dedicate this work to my beloved husband Shadrack and my sons John, Joseph, Moses, Leo and Antony for their collective moral support. I also dedicate the same to my friends relatives and associates for their encouragement which kept me focused throughout the preparation of this work.

ABSTRACT

Soybean varieties (Sable, Gazelle and SB19) were developed to improve soybean production in Africa. This study was therefore to investigate the effects of varying the rates of planting fertilizer sympal, and performance of the selected varieties (Sable, Gazelle and SB19). The experiment was carried out in one season at two sites; Bungoma County andssss Kakamega County from July 2013 to January 2014. Sympal fertilizer rates of 0 kg /ha, 200 kg / ha and 400 kg / ha were evaluated for their effects on the performance of the three soybean varieties (Sable, Gazelle and SB19) .The trial was a 3× 3 factorial experiment laid out in a Randomized Complete Block Design (RCBD). The treatments were replicated three times and each plot measured 4 m × 3 m. The parameters measured included ; Germination percentage, 50 % flowering, Plant height, number of pods per plant, 1000 grain weight (g) and grain yield (t / ha) The data obtained was subjected to Analysis of Variance (ANOVA) and the effects of treatments were separated using Least Significant Difference (LSD) test at $p \leq 0.05$. The results showed that;sympal fertilizer rates, and varieties significantly influenced the performance of soybean at both sites ($p \leq 0.05$) Sympal fertilizer rate of 200 kg / ha was significantly better than sympal fertilizer rate of 0 kg / ha and 400 kg / ha. And variety SB19 outperformed Sable and Gazelle varieties. in terms of germination percentage and grain yield. However, their effects in terms of 50% flowering, number of pods per plant and 1000grain weight were not significant. Sympal fertilizer rate of 200 kg per ha in combination with SB19 variety gave the best performance in the two areas and significantly outperformed all other combinations in Bungoma and Kakamega with respect to yields.This study therefore recommends the use of sympal fertilizer rate at 200 kg / ha in combination with SB19 variety for Bungoma and Kakamega.

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ACKNOWLEDGEMENT

I wish to acknowledge the invaluable and well-articulated support from my supervisors Dr. Nicolas Rop and Prof. Elmada Auma who guided me throughout the preparation and submission of this work. I also appreciate the work of Mary Pepela ; the Laboratory technician and her colleagues who assisted me curing the soil anslysis. I thank the farrmer in Bungoma Mr. Patrick Makhonge and the farmer in Kakamega Mr. John Osundwa for allowing me to use their land for my experiments in site 1 and site 2 respectively. I cannot forget the work of my research assistant Mr.Bonface Wanjala for his thorough work of data collection. I thank my colleagues and friends whom I am indebted for their moral and intellectual support during the entire period of my studies for M.Sc. degree in Agronomy. Finally, I wish to acknowledge the constant support from my husband; Shadrack, and the cheerful interest of my children; John, Joseph, Moses, Leo. And Antony whose time I borrowed to do this project.

CHAPTER ONE

INTRODUCTION

1.1 Importance of soybean

Soybean is the second most important legume worldwide after common beans. It is an oil crop/ legume which is utilized by half of Kenya's population (USDA, 2012). It is a principal source of carbohydrate protein and fat. It is a multipurpose crop that is grown for industrial oil production and human food, while it's by product can be used as livestock feed and more recently as a source of bio- energy (Myaka *et al* 2005). Unlike other legumes that contain about 20% protein, soybean contains about 40%. Soybean products are cholesterol free, high in calcium, phosphorus, fibre and have lowest levels of saturated fats. Soybeans are also rich in oil, Iron, most essential minerals and vitamins required by the body (Wafula *et al* 1999). People who suffer from different health problems such as diabetes benefit from soybean based diet (Greenberg and Hurtung 1988). Processed soybean products such as flour, oil, soya milk, soya beverage, snacks and processed chunks have a long shelf life. The soymilk is important for feeding babies with lactose intolerance. It is also an important source of income andss contributes to food security and can be processed at cottage and industrial levels. (CIAT, 2010).

1.2 Demand and production statistics of soybean

The demand for soybean is increasing in almost all African countries in pace with the rising population but production has failed to increase. Most countries including Kenya depend on imports to meet the short fall (Etsuo and Mbeya, 2003). It's demand in Kenya stands at 80,000 tons against the production of 5000 tons (Ministry of Agriculture economic survey publication, 2014). Sub- Sahara produced about 4 million tons of soybean in 2006 and imported 32% of it's requirement from the international market to meet it's demand. The importation cost is a big burden on the region's economy.

Due to population growth (4% per annum), rising incomes and a shift in consumer preferences in favour of soybean beverages and other products especially in urban areas, the relative growth in demand for soybean and its products is faster in this region than anywhere in the world (Kargana and Gachanja, 2004). Several and feed processing industries using soybean as raw material are located in various parts of Kenya. These processors import soybean for their uses.

1.3 Introduction of soybean varieties (Sable, Gazelle and SB19)

In order to narrow the gap between import and production of soybean, Sable (local) variety was introduced in Kenya in the early seventies and was first planted in the eastern region, i.e (Machakos and Makueni). Sable variety was introduced in western region (Homabay) in the mid seventies by Kenya Agricultural Research Institute (KARI) through ministry of Agriculture for bulking and distribution to farmers. It's characteristic of less moisture demand 350 – 400 mm during it's growing period has favored it's production especially as a short season crop. The cultivar takes 56 days from planting to flowering and 126 days to physiological maturity. It's plant height under optimal growing condition 60 to 63 cm and the crop can realize a yield of up to 1,600 kg / ha. It is known for its good oil content, of up to 35% (George *et al* 2003). The short coming of this cultivar is that it is vulnerable to soybean rust and is low in production (Ogot *et al* 2002). It's short growing period and early maturity has made it a favorable crop for growing in the rain shadow areas of western Kenya.

Gazelle variety was introduced in western region (Maseno) in the mid eighties by KARI through ministry of Agriculture for bulking and distribution to farmers. It's characteristic of soil acidity tolerance during it's growing period has favored it's production especially in the acidic areas of western Kenya with pH of 4.0 to 5.0. just like Sable,this cultivar takes 56 days from planting to flowering and 126 days to physiological maturity. Its plant height under optimal growing condition 55 to 57 cm and the crop can realize a yield of up to 2,600 kg / ha. It has oil content. Of up to 22% (George et al 2002)

SB19 is one of the varieties that was developed by Kenya Agricultural research centre (KARI, 2010) seed production programme. It performs well in all AEZs (0 2000m asl) in western region. It takes 56 days from planting to flowering and 126 days to physiological maturity. It grows up to an average plant height of 57cm and has an average seed yield of 2800 / kg ha and an oil content of 35%. SB19 is tolerant to soil acidity and has a positive response to fertilizer application. (Wafula et al 2009).

In the present study, effects of three sympal fertilizer application rates were used on three varieties; Sable (Local), Gazelle and SB19.

1.4 Problem statement

Soybean cultivation is rapidly expanding in Western Kenya but productivity remains low. Declining soil fertility, poor crop management practices and inappropriate matching of genotypes with environment are among the factors attributed to low soybean productivity (*Giller et al.,* 2013). Moreover, the available soybean genotypes are grown broadly without taking into account of their suitability/adaptability to the conditions prevailing in different agro-ecological zones (Mahasi et al., 2000). This situation is locking the expected benefits of soybean to poor households in terms of improving family nutrition, income and improved soil fertility (Chianu et al., 2009). Numerous options for soybean intensification in Western Kenya do exist for example, the use of improved genotypes, planting of soybean on fertile soil as well as improving agronomic practices including spacing and fertilizer application (Baijukya et al., 2010) However, the contribution of the above options to soybean yields under Western Kenya still remain poorly understood.

1.5 Justification of the study

Soybean yield losses lead to food and nutrition insecurity. In Kenya where common bean has been the dominant legume crop, the changing diets and food habits of majority of the people are increasingly rendering soybean an important crop, (FAO, 2008a). The demand for soybean in Kenya is increasing in pace with the rising population but production is much below the demand. Therefore the country depends on imports to meet the shortfall.. The development and bulking of soybean varieties Sable (local), Gazelle and SB19 has given new hope in the Arid and Semi arid lands of Kenya.ssss

Sable (local) variety was brought in Kenya from Nigeria in 1975 through eastern region to western Kenya. It was subjected to adaptability trials by the Ministry of Agriculture from 1979 to 1988 and the results showed that this variety was suitable for the two areas (Ministry of Agriculture, Kakamega, 2008).

Gazelle variety was introduced in western region (Maseno) in 1985 It's characteristic of soil acidity tolerance during it's growing period has favored it's production in western Kenya.

SB19 is one of the varieties that was developed by Kenya Agricultural research centre (KARI, 2010) in 1996 under the seed production programme. Is suitable for growing in all the in all the AEZs (0 2000m asl) in Kakamega and Bungoma.

However these three varieties Sable (local) Gazelle and SB19 are not performing to the required standards because of poor agronomic practices and this raises significant concern about both their performance and long term effects. The present study in the two areas was, therefore carried out to in order to shed more light on how to address these challenges.

1.6. Objectives

1.6.1 Overall objective

To contribute to increased soybean production in Kenya by choosing the right planting fertilizers, using the right application rates and right varieties

1.6.2 Specific objectives

i) To compare the performance of Sable (local) Gazelle and SB19 soybean varieties in relation to growth parameters of germination, 50% flowering, pod formation, and plant height and 1000 grain weights.

ii) To determine the effect of varying Sympal fertilizer rates on soybean grain yield.

1.7 Research Hypotheses (H1)

i) Application of Sympal fertilizer significantly influences the performance of Sable (local), Gazelle and SB19 soybean varieties.

ii) Varying the rates of application of sympal fertilizer significantly affect the performance of soybean varieties; Sable (local) Gazelle and SB19

iii) There is significant difference in performance amongst soybean varieties Sable (local), Gazelle and SB19

CHAPTER TWO

LITERATURE REVIEW

2.1 Classification of soybean

Soybean is classified according to the maturity period (CIAT 2002). Short maturity and long maturity varieties. The term short maturity refers to soybean varieties which take the shortest period of time to; flowering, pod formation and physiological maturity. On the other hand long maturity varieties refers to soybean varieties which take the longest period of time to flowering, pod formation and physiological maturity. (CIAT, 2000). Sable (local), Gazelle and SB19 are short maturity varieties (127 – 130 days) as compared to varieties like 'Hill 'and 'Red tanner' which takes 151 days.

2.2 Characteristics of soybean varieties Sable (local), Gazelle and SB19.

The above three varieties share the inherent characteristic of; early flowering and uniformity in pod formation (Kolol *et al* 2009; Hemal *et al* 2010). This facilitates the practice of relay cropping with vegetables and other short growing crops.

Sable variety is well adapted to local soybean production systems and it has some resistance to biotic and a biotic stresses such as weeds infertile soils and water logging (KARI, 2008). It has profuse early vegetative growth and thus helps in enriching soils through green manure. It's good foliage coverage reduces competition from weeds hence ensuring proper fertilizer utilization by the plant. (Jones *et al* 1998) however it possesses some traits of leaf curling and is very susceptible to soybean leaf rust. (CIAT, 2000).

Gazelle also has some resistance to biotic and a biotic stresses such as tolerance to soil acidity and water logging It has a short dormancy period and hence has a higher germination and root formation efficiency than other varieties Keter *et al* (2009) which ensures efficient fertilizer uptake by the plant as confirmed by Kolol *et al* (2010). It is a short variety and has profuse vegetation and is tolerant to lodging. It has a dense rooting system which increases it's efficiency in nutrient uptake. It also has a high yield potential of between 2600 – 2800 kg / ha (Atera et al 2006).

SB19 posses good agronomic traits coupled with high seed yield potential. It is very resistant to many biotic and a biotic stresses (Jones et al, 1998) Findings of (George *et al* 2003) indicate that SB 19 has an upright growth at reproductive stage which enables it to support heavy seed pods through maturity to harvest (CIAT, 2000). SB19 smothers weeds which helps to improve on it's nutrient uptake. It has a dense rooting system which ensures proper nutrient and water uptake by the plant. It resists drought and pests and is able to thrive in poor soils (Manners *et al*, 2002). With few additional inputs, the farmers growing SB19 can double production and raise incomes. The variety has carved a special niche as it perfectly adapts to the valley bottoms where farmers have serious drainage problems (Wafula and Wengo 2000). SB19 Is taller in height compared to other soybean varieties this coupled with it's open foliage system increases it's photosynthetic efficiency, flowering, pod formation and final crop yield (Hemal *et al* 2009).

According to Swaleh *et al,* (2009), Soybean varieties Gazelle and SB19 shade off leaves and mature 10 – 15 days earlier than other traditional varieties and thus allow farmers to grow extra crops like vegetables. Morever they produce 600 – 700 seeds. And contain 3% more oil content

than Sable and Gazsselle (George *et al* 2003) Gazelle and SB19.In addition they have the characteristic of wide erect leaves that help to suppress weeds and hence facilitate in the reduction of nutrient competition from the weeds. (Nzomeku *et al* 2007). With proper selection of the right fertilizers coupled with the right application rates, yields of the three varieties, Sable (local), Gazelle and SB19 can be doubled or even tripled. (Olga *et al* 2002). According to Wafula and Wengo (2008), the seed yield of Gazelle and SB19 increases significantly by increasing P and K supply to soils Keter and Omami (2009) also showed that soybean germination and subsequent crop yield improves through addition of P and K fertilizers in humid forests and semi arid lands and recommended application of 45 kg -50 kg of P and 30 to 35 kg of K /ha to double Gazelle and SB19 seed yield.

Kijima and Webi (2006) stated that Gazelle and SB19 yields in Uganda were twice as compared to Sable (local) variety and other local varieties in the sub Saharan Africa with an average yield in the farmers' fields being 3.2 tons / ha .From From 2005 to 2010,on farm bulking sites were established by the Ministry of Agriculture in Kakamega and Gazelle yields of 2.9 tons and SB19 yields of 3.1 tons / ha were achieved. Kenya Agricultural Research Institute (KARI) Kakamega site between 2007 to 2008 at their seed multiplication plots also established that Gazelle variety gave yields of 3.0 tons /ha, SB19 gave 3.2 tons ha while Sable (local) gave 1.6 tons / ha. (KARI 2009).

Performance of soybean varieties is reflected through plant establishment and the grain yield. And this can be affected by lack or inconsistent use of fertilizer and poor choice of variety. Germination percentage, and plant height are some of the most important indicators of plant establishment. (CIAT 2010).

2.3 Ecological requirements of soybean

Soybean is a short-day plant. In Kenya, soybeans are grown in the maize growing areas, mainly by small-scale farmers. Amongst several climatic factors affecting soybean cultivation, temperature is one of the important factors. The efficiency of growth is observed when temperatures range between 18 – 28^0C. Research has however, shown that various soybean varieties exhibit different responses to temperatures (Anon et al 2002).

Temperatures below 21°C and above 32°C can reduce floral initiation and pod set. If water is available, soybeans can be grown throughout the year in the tropics and subtropics. Soybean requires 400 to 500 mm in a season for a good crop. High moisture requirement is critical at the time of germination, flowering and pod forming stage. However, dry weather is necessary.

2.3.1 Soil factors

Soybean thrives well in well drained red, brownish or dark brown soils. PH of 6.5 – 7.0 with adequate organic matter are the best soils for growth (FAO 2008b).It is sensitive to soil acidity. Ideal soil for optimum soybean production is a loose, well-drained loam. Many fields have tight, high clay soil that becomes waterlogged when it rains. When the soil dries out, a hard crust surface may form which is a barrier to emerging seedlings. These high clay soils are low in humus and may have imbalance in mineral nutrients. Also, these soils may have few beneficial soil organisms (bacteria, fungi, algae, protozoa, earthworms and others). High clay soils may be amended with peat moss, sphagnum, organic mulch to increase the humus content. Sand may be added to loosen and aerate the soil and allow better drainage.

The advantages of loose, well-aerated soil include; movement of air to roots and nitrogen-fixing root nodules, increased water-holding capacity with adequate drainage, reduced erosion, reduced weed populations, maintenance of steady and balanced nutrients to roots and balance pH, and increased potential to protect roots from harmful nematodes, insect pests, and pathogens

2.3.2 Propagation, planting, husbandry and harvesting.

Soybeans are propagated by seed. However soybean seed looses viability within 6-10 months depending on the variety and the environmental conditions, especially under hot and damp conditions. Test seed for viability before planting: take 100 seeds from about 3 places in the seed lot, put each lot of 100 seed in a glass of water for 24 hours, then drain off the water and replace with damp cotton wool or a damp cloth. Keep cloth damp - after 3-4 days young sprouts will have formed on all viable seed, and it is easy to count how many out of the 100 that has germinated (germination percent). Germination percent above 85 is regarded good. Soybeans are sown in rows 40-50 cm apart and within rows the seeds are either drilled or planted 10 cm apart. Seed rate is 60-70 kg / ha.

Under husbandry, weed control is essential. Early seed bed preparation with removal of couch and water grass is the first step to good yields. Irrigation at flowering and during seed filling is essential to gain optimum yield. More frequent irrigation is needed in sandy, well-drained soils than in heavy clay soils. Favorable effects of soybeans are improved soil structure and fertility due to its nitrogen fixing capacity.

Soybeans can obtain all of their nitrogen needs from the air when nitrogen-fixing-rhizobia (bacteria) are present in the soil. Nitrogen fixation is a result of the symbiotic relationship of rhizobia and the plants. Where soybeans have not been grown before it may be beneficial to treat the seed with soybean inoculums available from University of Nairobi - Kabete campus,(Dept. of Soil Science) at a rate of 100g/15kg seed before planting to allow maximum nitrogen fixing throughout the growing season. A well-nodulated plant should have around 5-7 nodules on the primary root. When plants have fewer nodules, monitor the field carefully to determine if the nodule numbers increase. Nitrogen deficiency results in reduced chlorophyll development and a pale-green leaf color (Baijukya et al., 2010).

Do not add nitrogen to well-modulated soybeans. It is just a waste of time and money. Nitrogen added during planting delays nodulation and when applied during the vegetative stage results in poor nodule formation in proportion to the rates applied. However phosphorus in the form of rock phosphate at a rate of about 100-150 kg/ha is very beneficial for good root formation (Chianu et al.,2009). Sanginga et al.,(2003) estimated that soybean can fix between 44-103kg N/ha Under harvesting, early-maturing cultivars can be harvested for grain 125 days after planting and late maturing cultivars need up to

180 days. The plants are cut near the ground or pulled with their roots at physiological maturity when most leaves have aged and turned yellow, and at least one pod per plant have turned brown or black. Vegetable soybeans are harvested when the pods are still green but when the seeds have filled the pod.

Most small scale farmers achieve yields of about 500-1000 kg/ha, though 3000 kg/ha is possible with good husbandry practices (Eglin, 1998). Soybeans can be harvested by hand or by combine harvesters (this only at full maturity or after windrowing - cutting plants and leaving them in rows for wind and sun to dry properly). Once threshed, dry the soybeans to below 12 % moisture content before storing. Keep in a clean store and prevent weevil attack by any of the means described under storage pests. Seeds meant for seed should not be stored for longer than 1 year due to rapid loss of germination capability. (Asea et al ., 2010)

2.4 Use of fertilizers in Soybean production

The main nutrients required for optimum soybean production are; nitrogen, phosphorus, potassium and calcium, and to a lesser extent sulfur and magnesium. (Australian Department of Agriculture and Food 2007).

Soybean needs a high level of soil fertility to produce high yields. A 3.4 t/ha crop of soybeans contains 134 kg of nitrogen, 27 kg of phosphate and 54 kg of potash a. A common misconception is that soybeans respond only to residual fertilizer from the previous crop. Research has shown that soybeans respond not only to residual fertilizer, as all crops do, but to applied fertilizer as well (Wilcox and Bendo 1987).

Soils vary considerably in their ability to supply nutrients, depending on soil type and past management.

Healthy plants need various amounts of nutrients from the soil. Some nutrients are required in large amounts (macronutrients) and some in small amounts (micronutrients). Most soils either have deficiencies or imbalances in the amounts of nutrients available to the plants. Here is a brief summary of the soil nutrients:

Nitrogen is a macronutrient and needed by the plant for certain enzyme functions, to make proteins, and as a necessary part of chlorophyll, nucleic acids, vitamins and several other substances. Soybeans can obtain all the nitrogen they need from root nodule nitrogen-fixing bacteria. Soybean is a legume which normally provides itself with adequate nitrogen through a symbiotic relationship with N-fixing bacteria of the species *Bradyrhizobium japonicum*. In this symbiotic relationship, carbohydrates and minerals are supplied to the bacteria by the plant, and the bacteria transform nitrogen gas from the atmosphere into ammonium-N for use by the plant. In fact, in tests where fertilizer nitrogen was added to soil, no yield increase occurred, plus the root nodules fixed less nitrogen Woomer et al ., 2011)

Phosphorus is a macronutrient and is needed for general growth and metabolism and for photosynthesis. It carries energy from one part of a cell to another and helps transport food from one part of the plant to another. It also makes up part of cell membranes, nucleic acids and other components. It is necessary for growing really high quality crops. Young seedlings especially need phosphorus. The most efficient and economical way to get phosphorus to crop plants is to maintain soil with adequate levels of humus/organic material and beneficial soil microbes which decompose organic matter to release phosphorus and nutrients to plants (Sanginga and Woomer, 2010).

Potassium is a macronutrient and is needed for the plant's enzyme functions, food transport, protein and chlorophyll production, and in regulating water balance, potassium is needed by soybeans in fairly large amounts. Most soils contain large amounts of potassium which are tied up and not available to plants. Soil microbes function to release potassium and other nutrients to plants.(*Samake et al* 2005).

If the soil is very low in potassium, a suggestion for an overall fertilizer source is potassium sulfate (0-0-50). Avoid using fertilizer formulations with chloride because the chloride ion can injure soil microbes as well as soybeans themselves if present in high amounts. Potassium sulfate is more expensive than potassium chloride, but only about one-half as much is needed, and the extra sulfur is usually beneficial.

Calcium is a macronutrient and is very important for growing high quality soybeans. Calcium is critically important for cell division, root hair growth, enzyme functions, and production of normal cell walls. Calcium improves plant's resistance to disease and gives higher quality, more nutritious crops

In the soil, calcium and magnesium "compete" for plant absorption. Too much magnesium disrupts the plant's uptake of calcium and potassium, causing low quality crops. Additionally, excess magnesium causes soil to develop hard, crusty conditions. Most soils should have adequate magnesium. In general, soils in the western two-thirds of the U.S. have adequate calcium, while those in the eastern one-third may be deficient (Zingore et al ., 2008)

The best source of calcium is high-calcium lime (calcium carbonate) which has low magnesium and dissolves quickly in water. In alkaline soil, gypsum (calcium sulfate) is the best source of calcium.

Sulfur is a macronutrient and is needed to build proteins and assist enzyme functions. Many soils have adequate sulfur because of air pollution from burning high-sulfur coal, but some soils are deficient.

If sulfur is needed for healthy soil, the most readily available source is sulfate-containing fertilizers (calcium sulfate, potassium sulfate). Elemental sulfur (flowers of sulfur) is slow to release and become available. Baijukya et al (2013)

Micronutrients are required by plants in small amounts and include iron (Fe), zinc (Zn), copper (Cu), boron (B), manganese (Mn), molybdenum (Mo), cobalt (Co) and chlorine (Cl). Molybdenum is needed by nitrogen fixing bacteria. In soybeans, the most frequent micronutrient deficiencies are for iron, zinc, manganese and molybdenum. But such deficiencies usually occur in poor, weathered or sandy soils, or in soils that are very alkaline or excessively high in organic matter (mucks and peats). A loamy soil with adequate humus and soil life should not have micronutrient deficiencies. If a micronutrient is deficient in your soil, only that element should be added. Too much of some micronutrients will be toxic Khan and Muhamad, (2008) Nutrient Balance and PH. For healthy crops and high quality yields, nutrients must be available to the plants in the proper amounts and in the right balance. The soil pH (acidity or alkalinity) affects the availability of soil nutrients to plants. The pH scale is expressed as a numerical scale ranging from 0 (most acid) to 14 (most alkaline), with a 7 being neutral. Soybeans grow best in slightly acid soil but can tolerate a wide range of pH (pH 5.8 to 7.0). Soil pH also affects the types and ability of soil organisms to live, including nitrogen-fixing bacteria. Humus in soil will buffer extremes in pH, and lime can be added to amend soil and counteract acid soil. (USDA 2010)

2.4.1 Importance of phosphorus in soybean crop performance

Phosphate and other nutrient ions are important for cell division**,** formation of fibrous roots and for development of meristematic tissues (Nye and Tinker 1977).According to Benton, (1998), phosphorus is an important constituent of chromosomes and is important for protein formation and enzymes. Other specific growth factors associated with phosphorus include, increased stalk and stem length, improved flower formation and seed production, more uniform and earlier crop maturity, improved crop quality and increased resistance to plant diseases. (Chianu et al., 2009)

2.4.1.1 Symptoms of Phosphorus deficiency

Deficiency includes stunted growth with dull green or blue green color. Plants become slender and thin, stems and seed color development is poor. Red or purple color forms on the underside of leaves including the veins, delayed maturity and roots become brown and develop few integral branches. When respiration is restricted due to phosphorous shortage, sugars are not converted into energy and they accumulate within the plant tissue. Accumulation of the unused sugars leads to the purple coloration. The low energy level within the plants is the underlying cause of stunted growth seen with phosphorus deficiency.

2.4.1.2 Management

Extra Phosphorus should be applied on soils that are prone to chemical locking. The applied phosphorus, such as the calcareous and ironstone soils Phosphate is needed during early growth. So phosphatic fertilizers are applied at planting time.(Australian Department of Agriculture and Food,2007).

2.5 The effect of Sympal fertilizer on soil properties and yield

Is a fertilizer blend, Sympal 0-23-16 plus Ca, Mg and S, which was developed in response to soil conditions and plant deficiency symptoms, and later commercialized alongside other specialty blends by MEA Fertilizer Ltd.

It is a compound fertilizer that contains the two major nutrients phosphorus and potassium. In addition, it contains other important nutrients such as calcium, magnesium and sulfur. It has an advantage over the other planting fertilizers because it contains extra elements that are important for soy bean growth development and productivity. The added advantage of the use of Sympal fertilizer makes it unnecessary to use lime in soils that are acidic because Sympal fertilizer contains calcium at levels that are sufficient to reduce acidity within a shorter period of time (two planting seasons) as compared to liming. in soy beans which takes up to three to four years before the acid levels are reduced.(CIAT 2010).Challenges of availability of lime including increased expenses incurred in the process of sourcing for lime have been solved through use of sympal fertilizer. The fertilizer has been made available through *MEA CO*. which has established stockists in the whole of western region. (CIAT 2000).

Inspite of the fact that sympal fertilizer was specifically blended for use in legume production in order to address the legume production constraints,a lot of research has been biased towards it's use on the common bean genotypes (KARI 2005). Rahman et al., (2011) only worked on fertility requirements of three accessions of soybeans around the lake region on soils which had not been adversely affected by use of acidifying fertilizer .Local soybean accessions such as Sable and some of the promiscuous genotypes have been grown in Bungoma and Kakamega using residual fertilizers and yields have been as low as 0.2 t/ha. This research is meant to address soil fertlilty gaps at the study sites because the dominant fertilizers used have been very acidifying to the soils. This has impacted negatively on soybean yields. Hence this calls for research to be done in this area in order to address issues of low Ph and nutrient fixation that has been rendering nutrients unavailable to the soya crop.

CHAPTER THREE

MATERIALS AND METHODS

3.1 Study sites

3.1.1 Location of the study sites

Field experiments were conducted at two sites; Bungoma South sub county of Bungoma county (Sio village) at Patrick Makhonge's farm which is 2 km off Bungoma –Mumias road (Figure 2).It is situated 5 km south of Bungoma town It's geographical coordinates are 0° 34' 0" North, 34° 34' 0" East. at an elevation of 1450m. Above sea level. It's ecological zone is lower marginal zone 2 (LM2). (Jaetzold, 2006), with average rainfall of 1100 -1300 mm per annum.The area experiences both long rains and short rains. The area is characterized by highly weathered and well drained soils. The soils are acidic with a pH of 5.0.

The second site for the study was at Matungu village located 20km north of Mumias town and it's geographical coordinates are 00' 35'0'' North, $35^0$35'0'' East. At an elevation of 1000m. above sea level. It's ecological zone is lower marginal zone 3(LM_3). (Jaetzold, 2006), with average rainfall of 800 -1000 mm per annum. The area experiences both long rains and short rains. The soils are highly weathered and sandy with a pH of 4.7

The two sites were chosen because they fall under low and medium altitude zones that are recommended for soybean growing

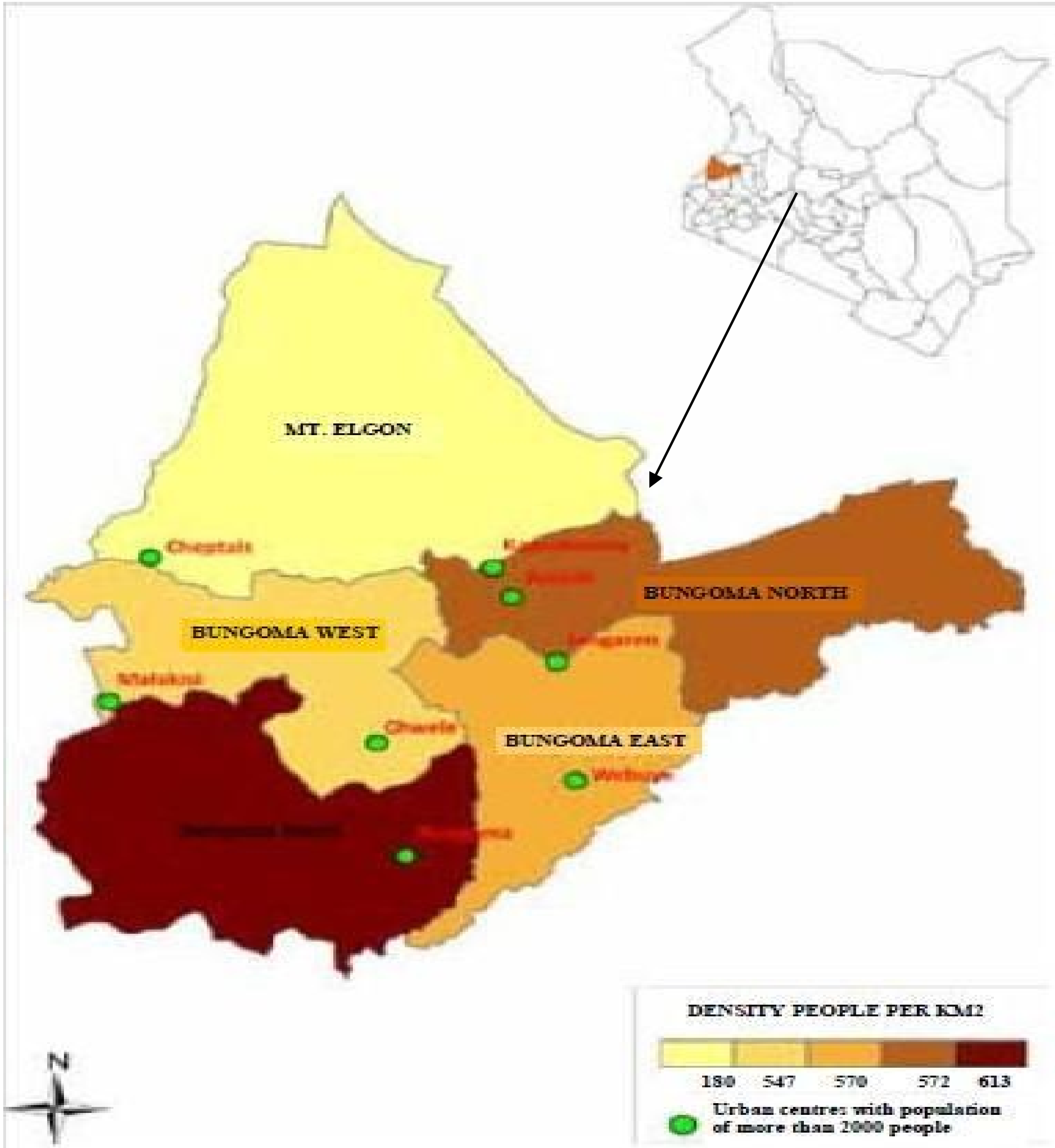


Figure 1: Map of Bungoma County showing the first study site (Sio village).

Patrick Makhonge's farm (study site)

(Source: Ministry of Agriculture Bungoma County, 2012)

Figure 2: Map of Kakamega County showing the second study site (Matungu village). John Osundwa's farm (host)

(Source: Ministry of Agriculture Kakamega County, 2012)

3.1.2. Land use of the experimental sites

At Bungoma site, the experiment was set up in August2013 on a farmer's field which had been under maize and beans cultivation 2011 and 2012. The farm was under medium level of management with heavy use of mineral fertilizers (DAP, urea and CAN). At Kakamega site, the experiment was carried out on land which had been left fallow for two cropping seasons. The land was currently under natural pastures. The field was situated on a gentle slope. Previously the land was under maize and beans

3.1.3. Soil characterization

Soil samples were taken from each site and analyzed in the laboratory for status characterization of the sites, to determine the soil Ph, total Nitrogen ,and available Phosphorus (Olsen).as described in Okalebo *et al* (2002) The results of the test showed that, the soils at Bungoma site had a pH of 5.0 while those of Kakamega showed that the pH was 4.7 indicating that both sites were acidic.The total Nitrogen in the soil in Bungoma and Kakamega was found to be 0.06 and 0.05 respectively, while available Phosphorus was recorded at 8.80 P (ppm) and 8.70 (ppm) respectively. Percentage carbon was 2.00 and 1.94 respectively, Bulk density was 1.55 and 1.50 respectively, while field capacity was 41.7% and 42.0% respectively.

Under chemical and physical properties of the soil, both experimental sites had texture class of sand loams with 61% and 71% sand,14% and 8% clay and 25% and 21% silt respectively.

According to Okalebo *et al* (2002) It was evident that nitrogen and phosphorus were deficit and both sites were acidic. hence the felt need of using a type of fertilizer that would improve the soil status and increase soybean yields.

3.2 Treatments

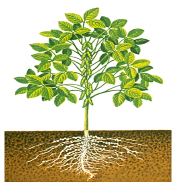
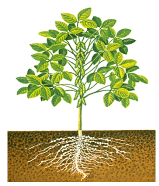
3.2.1 Sympal fertilizer rates.

Sympal fertilizer rates used in the experiment were; 0 kg / ha (zero supply of Phosphorus) , 200 kg / ha sympal fertilizer (to supply 46 kg / ha of phosphorus) and 400 kg / ha of sympal fertilizer (to supply 92kg / ha of phosphorus. The rationale behind the choice of the above fertilizer rates was based on soil samples that were tested for N P and K which indicated levels of 0.08 %, 4.45mg kg^{-1} and 0.7% respectively. The rates applied were based on the nutrient deficits that were calculated basing on the soil nutrient status.

3.2.2 Varieties

Three soybean varieties were studied: Sable (local), Gazelle and SB 19. Which were selected from the list of soybean varieties in Kenya These were chosen because they have been recommended for Bungoma and Kakamega by Ministry of Agriculture Characteristics of the three varieties are shown in the table below:.

Table 1: Characteristics of soybean varieties (Sable (local), Gazelle and SB19)

Variety	Sable	Gazelle	SB19.
 			
Production altitude (masl)	0 - 2200	0 - 2200	0 – 2200
Emergence percentage	78	90	85
Days to flowering	56	56	56
Days to physiological			
Maturity	132	133	133
Plant height (cm)	55	53	57
Seed yield kg / ha	1600	3000	3300
Oil content (%)	17.9	22.0	23.0
Protein content (%)	35	35	35

Source: George *et al* (2008)

3.2.3 Treatment combinations

The treatments were combined as follows:

S2V1, S3V2, S1V3, S3V1, S2V3, S3V3, S1V2, S2V2, S1V1 giving a total of nine treatments.

Where; S1 = Sympal fertilizer rate of 0 kg / ha (phosphorus rate of 0 kg / ha)

S2 = Sympal fertilizer rate of 200 kg / ha (phosphorus rate of 46kg / ha

S3 = Sympal fertilizer rate of 400 kg / ha (phosphorus rate of 92 kg /ha

V1 = Sable (local) variety

V2 = Gazelle variety

V3 = SB19 variety

3.3 Experimental Design and plot layout

3.3.1 Experimental Design

The experimental design was a 3x3 factorial in a Randomized Complete Block Design (RCBD) with three rates of fertilizer application (Sympal fertilizer rate of 0 kg/ha (phosphorus rate of 0 kg/ha, Sympal fertilizer rate of 400 kg/ha (phosphorus rate of 92 kg/ha), and Sympal fertilizer rate of 400 kg/ha (phosphorus rate of 92 kg/ha).and three varieties (Sable-local, Gazelle, and SB19). The treatments were replicated three times 3 times making 27 plots at each site. Each plot measured 4 m × 3 m.

3.3.2 Field Layout

The experiment was laid out as shown in Figure 3.

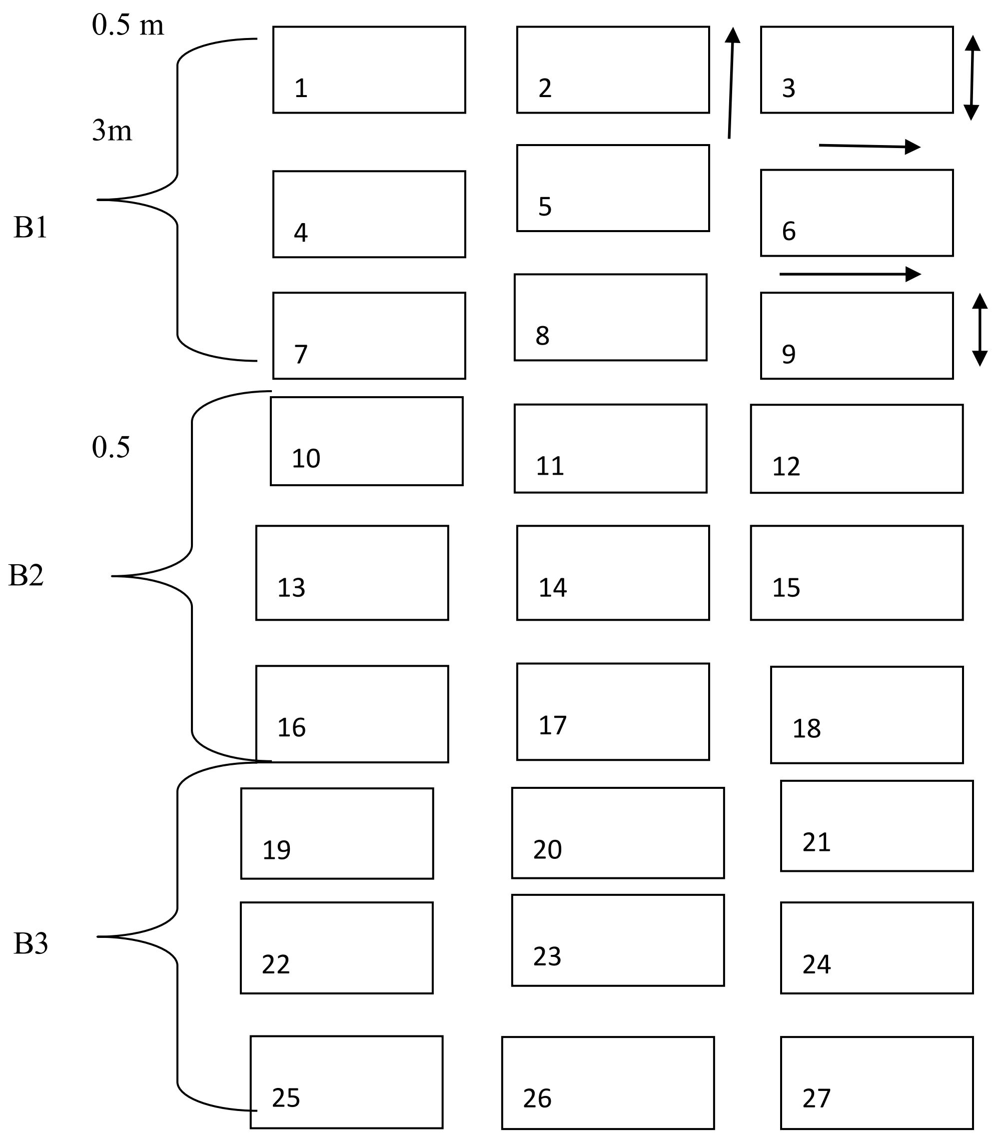


Figure 3: Field layout

Key: S1 = Sympal fertilizer rate of 0 kg / ha (phosphorus rate of 0 kg / ha)

S2 = Sympal fertilizer rate of 200 kg / ha (phosphorus rate of 46kg / ha

S3 = Sympal fertilizer rate of 400 kg / ha (phosphorus rate of 92 kg /ha V1 = Sable (local) variety

V2 = Gazelle variety

V3 = SB19 variety

3.4 Cultural practices

3.4.1 Land preparation

Land preparation was done in August and September 2013 at both sites using an oxen plough for the first and second ploughing, and harrowing was done by hand

3.4.2 Determination of seed quality

Sable (local). Gazelle and SB19 seed was sourced from KARI – Kakamega and emergence test was carried out to know whether the seed was viable. The emergence percentage of each variety was calculated using the formula below:

$$Emergence\ \% = \frac{Number\ of\ seedlings\ emerged}{Total\ number\ of\ seeds\ sown} = \times 100$$ Asea *et al* (2010)

The results of the emergency test showed an emergency percentage of 80%,90% and 85% respectively for Sable (local), Gazelle SB19 and therefore the seed were of good quality (> 80 %)

3.4.3 Planting

The seed was uniformly planted to field plots. A seed rate of 60 kg /ha was used as per the recommendation of Opera *et al* (1998) Row planting was done manually. Holes were prepared using small jembes.Three seeds were planted per hole at a depth of 3 cm and covered with a thin soil layer to ensure even seed germination Soy bean spacing was done at 45 cm ×. 10 cm.

3.4.4. Fertilizer application

Compound fertilizer Sympal fertilizer was applied to all the treatments in the plots. At varying rate as below Sympal fertilizer rate of 0 kg / ha (phosphorus rate of 0 kg / ha), Sympal fertilizer rate of 200 kg / ha (phosphorus rate of 46kg Sympal fertilizer rate of 400 kg / ha (phosphorus rate of 92 kg /ha. The fertilizer was applied once at planting time. It was properly mixed with the soil before placement of the seeds. This type of fertilizer was chosen due to the prevailing acidity in the soils at the study sites.

3.4.5 Weeding

This was done through hand weeding at

14 and 35 days after planting.

3.4.6. Pest and water management

Incidences of pests were monitored and broad spectrum insecticides were applied to control the pests. Supplementary irrigation was done to all the plots as need arose.

3.4.7 Harvesting

The crop was harvested at physiological maturity by cutting the stems 10 cm above the ground using a sickle and then dried and threshed.

3.5. Parameters measured

a Emergence percentage

Literal counting of the emerged seedlings was done five days from the day of planting, and the emergence percentage formula was used.

$$Emergence\ \% = \frac{\text{Number of seed emerge}}{Total\ number\ of\ seeds\ sown} \times 100$$

b. Determination of 50% flowering.

A 1 m × 1 m grid quadrat was placed at the centre of each plot and the number of plants that had flowered were counted the means for the plants that had flowered per treatment were calculated. This was done 60 days from the planting date. This parameter was important in confirming the inherent characteristics of the soybean varieties,

c. Number of pods per plan

Pods from ten randomly identified plants per treatment were literally counted. the mean number of pods was then calculated per treatment using the initial recorded data. This was done 90 days from the panting date.

d. Plant height

A 1 m × 1 m grid quadrat was placed at the centre of each plot and plant height was scored at pod formation stage by measuring the height of 10 plants in the quadrat a ruler was used to measure the height from the ground level to the tip of the plant.

e. One thousand grain weight

This was done at the physiological maturity stage whereby five plants from each plot were randomly uprooted, and 1000 seeds were removed from the pod, were counted and weighed.. The weight of each 1000 seed from sample was compared to the fertilizer rates and the varieties used in relation to the final crop yield

f. Grain yield,

The grain yield was determined at harvest by weighing the amount of grain for each variety from 1.2 m2 at the centre of each plot

3.6 Data analysis

The data obtained was subjected to Analysis of Variance (ANOVA).and the means of effect were separated using least significant difference (LSD) test at $P \leq 0.05$ (SAS institute, (1987).

The statistical model used was

$Yijkl = \mu + Bi + Vj + Sk + Vj\,Sk + Eijklm$

Where, $Yijkl$ = Observations on experimental units due to $ijkl^{th}$ *factors*

μ = Overall mean

Bi = Effect due to i^{th} block

Vj= Effect of j^{th} variety

Sk = Effect of k^{th} Sympal

$VjSk$ = Interaction effect of j^{th} variety and k^{th} Sympal rat

$Eijklm$ =Experimental error

CHAPTER FOUR

RESULTS

4.1 Effects of Sympal fertilizer rates and varieties on emergence percentage

The effects of the treatment on emergence of soybeans are shown in table 3 and Appendix 11a and 11b.There were no significant differences ($p \leq 0.05$) between varieties and sympal rates, both in Bungoma and Kakamega

Table 2: Effect of Sympal fertilizer rates and varieties on percentage emergence

Bungoma					**Kakamega**			
Treatment	**Sable**	**Gazelle**	**SB19**	**Mean**	**Sable**	**Gazelle**	**SB19**	**Mean**
Sympal (0 kg)	81.1	86.0	86.0	**84.4** a	81.0	86.0	81.0	**82.7 a**
Sympal (200 kg)	87.0	86.2	81.1	**84.7 a**	83.0	86.0	80.0	**83.0 a**
Sympal (400 kg)	86.2	81.1	87.0	**84.8 a**	82.0	80.0	86.0	**82.7 a**
LSD $_{0\cdot05}$				ns				ns
Mean	**84.8 a**	**84.4 a**	**84.7 a**		**82.0 a**	**84.0 a**	**82.3 a**	
LSD $_{0.05}$				ns				ns
C.V. %				10.9				15.9

Key: Means within a row or column with different letters are significantly different ($P \leq 0.05$)

Table 3: Effects of Sympal fertilizer rates and varieties on days to 50% flowering of soybeans

	Bungoma				Kakamega			
Treatment	**Sable**	**Gazelle**	**SB19**	**Mean**	**Sable**	**Gazzelle**	**SB19**	**Mean**
Sympal (0 kg)	67.0	68.0	66.0	**67.0** a	65.3	65.2	65.0	**65.2 a**
Sympal (200 kg)	68.0	66.0	67.0	**67.0 a**	65.4	66.0	64.2	**65.2 a**
Sympal (400 kg)	67.5	59.2	64.0	**63.6** a	65.3	65.0	65.4	**65.1** a
LSD $_{0\cdot05}$				ns				ns .
Mean	**67.5 a**	**64.4 a**	**65.7 a**		**65.3 a**	**65.4 a**	**64.9 a**	
LSD $_{0.05}$				ns				ns.
C.V. %				11.0				22.4

Key: Means within a row or column with different letters are significantly different (P≤ 0.05)

Table 4: Effects of Sympal fertilizer rates and varieties on plant height (cm).

	Bungoma				Kakamega			
Treatment	**Sable**	**Gazelle**	**SB19**	**Mean**	**Sable**	**Gazelle**	**SB19**	**Mean**
Sympal (0 kg)	45.0	53.3	53.0	**47.7** a	47.0	49.0	55.0	**50.3 a**
Sympal (200 kg)	53.5	46.0	46.0	48.2 **a**	54.0	48.0	50.0.	**50.6** a
Sympal (400 kg)	46.5	45.0	45.0	**47.7 a**	48.0	46.0	44.0	**46.0 a**
LSD $_{0.05}$	ns		ns					
Mean	**48.0 a**	**48.1a**	**48.0 a**		**49.7 a**	**47.7 a**	**49.7 a**	
LSD $_{0.05}$		ns					ns .	
C.V.%			**4.8**				**6.1**	

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Key: Means within a row or column with different letters are significantly different (P≤ 0.05)

Table 5: Effects of Sympal fertilizer rates and varieties on number of pods per plant.

	Bungoma				Kakamega			
Treatment	**Sable**	**Gazelle**	**SB19**	**Mean**	**Sable**	**Gazelle**	**SB19**	**Mean**
Sympal (0 kg)	30.0	40.0	40.0	**36.7 a**	37 .0	38.0	38.0	**37.7 a**
Sympal (200 kg)	33 .0	40.0	40.0	**37.7 a**	36.0	37.0	39.0	**37.3 a**
Sympal (400 kg)	32.0	39.0	40.0	**37.0 a**	37 .0	38.0	38.0	. **37.7 a**
LSD $_{0.05}$				**ns**				**ns** .
Mean	**31.7 a**	**39.7 a**	**40.0 a**		**36.7 a**	**37.7 a**	**38.3 a**	
LSD $_{0.05}$				ns				ns
C.V. %								6.1

5.9 Key***: Means within a row or column with different letters are significantly different (P≤ 0.05)***

Table 6: Effects of Sympal fertilizer rates and varieties on 1000grain weight (g).

	Bungoma				Kakamega			
Treatment	**Sable**	**Gazelle**	**SB19**	**Mean**	**Sable**	**Gazelle**	**SB19**	**Mean**
Sympal (0 kg/ha)	75.0	68.0	70.5	**71. 2 a**	71.0	69.0	70.0	**70.0 a**
Sympal (200 kg/ha)	72.5	69.8	74.0	**72.1 a**	74.0	72.0	73.0	**73.0 a**
Sympal (400 kg/ha)	73.0	70.3	72.5	**71.9** a	72.6	73.5	71.0	**72.4 a**
LSD $_{0.05}$				ns				ns
Mean	**73.6a**	**69.4 a**	**72.3 a**		**72.5 a**	**71.5 a**	**71.3 a**	
LSD $_{0.05}$			ns					ns
C.V. %			2.8					5.2

Key: Means within a row or column with different letters are significantly different ($P \leq 0.05$)

Table 7: Effects of Sympal fertilizer rates and varieties on grain yield (t /ha)

	Bungoma				Kakamega			
Treatment	**Sable**	**Gazzelle**	**SB19**	**Mean**	**Sable**	**Gazzelle**	**SB19**	**Mean**
Sympal (0 kg)	3.40	3.20	4.07	**3.56ab**	2.01	3.51	3.00	**2.84 c**
Sympal (200 kg)	2.20	4.77	5.80	**4.26** a	2.22	4.78	5.79	**4.26 ab**
Sympal (400 kg)	2.00	3.50	3.00	**2.83 bc**	3.41	3.22	4.05	**3.56 bc**
LSD $_{0\cdot05}$				1.2				1.3
Mean	**2.53 c**	**3.82 b**	**4.29 ab**		**2.55 a**	**3.84 a**	**4.28 a**	
LSD $_{0.05}$				1.0				1.4
C.V. (%)				11.8				20.2

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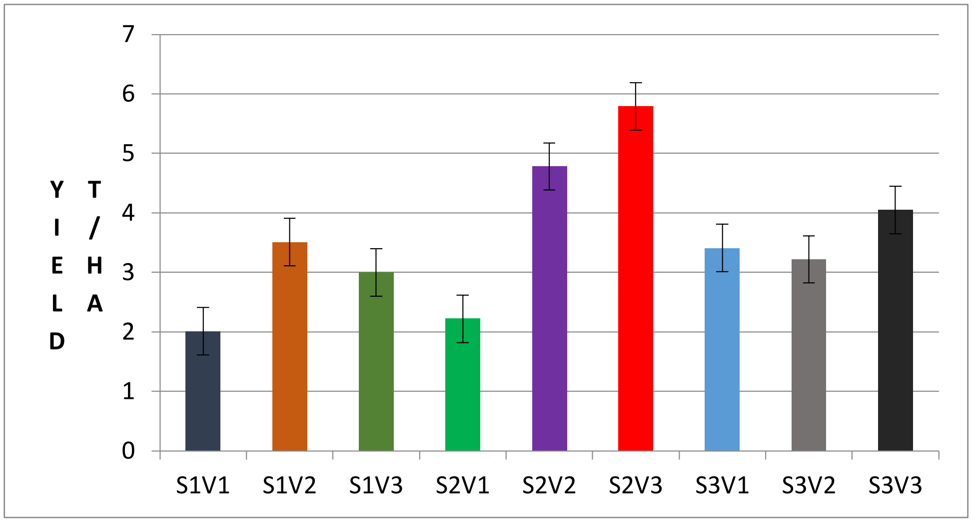
Key: Means within a row or column with different letters are significantly different (P≤ 0.05)

4.7.1nteraction between sympal fertilizer rates and varieties on grain yield.



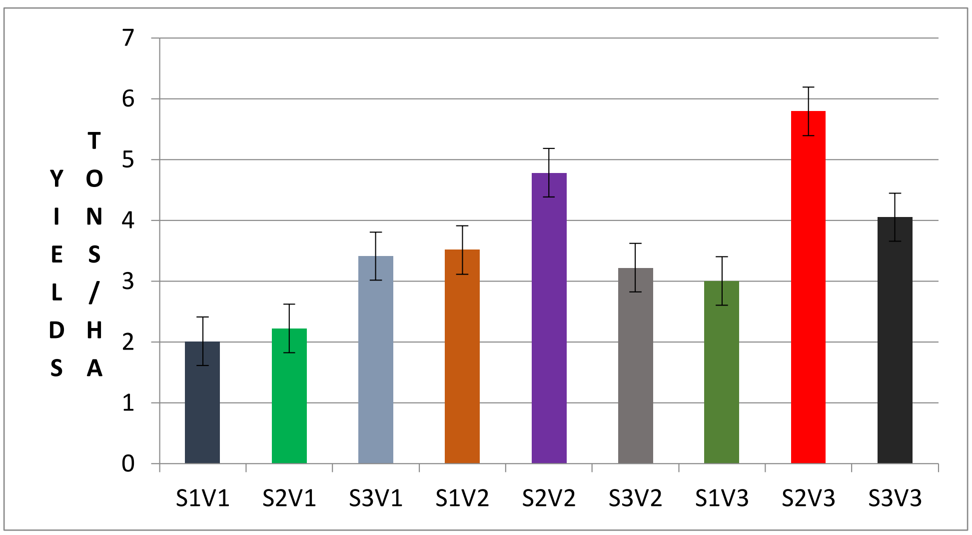


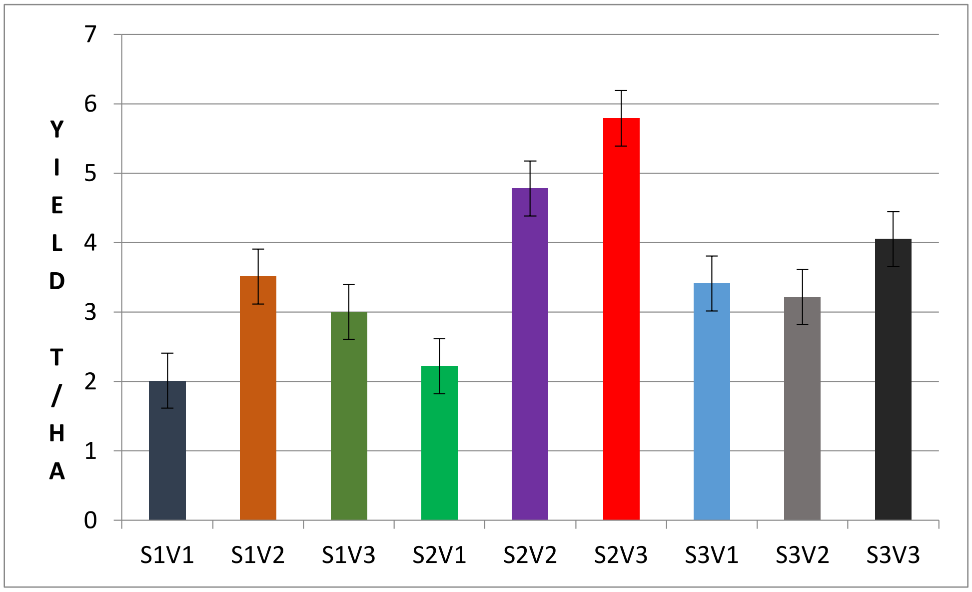
Figure 4: Interaction between sympal fertilizer rates and varieties on grain yield t/ha. (Bungoma County)

KEY:

S1= Sympal @ 0 kg/ha V1 = Local (Sable) variety

S2 = Sympal @ 200 kg/ha V2 = Gazelle variety

S3 = Sympal @400 kg/ha V3 = SB 19 variety



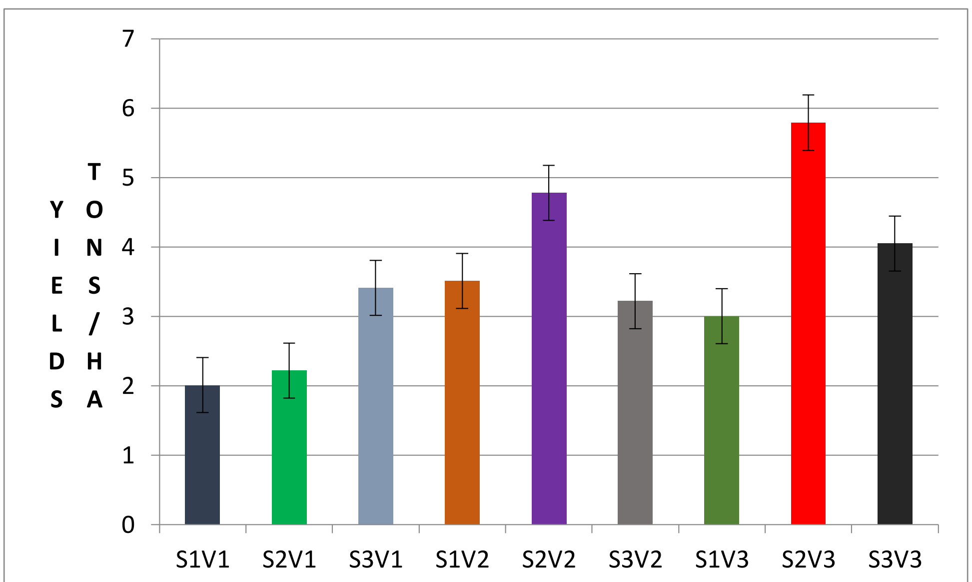


Figure 5: Interaction between sympal fertilizer rates and varieties on grain yield **t/ha.(Kakamega County)**

KEY:

S1= Sympal @ 0 kg/ha	V1 = Local (Sable) variety
S2 = Sympal @ 200 kg/ha	V2 = Gazelle variety
S3 = Sympal @400 kg/ha	V3 = SB 19 variety

CHAPTER FIVE

DISCUSSION

5.1 Effect of sympal fertilizer rates and varieties on emergency percentage.

From the study, all the three sympal fertilizer rates, 0 kg/ha, 200 kg/ha and 400 kg/ha did not indicate any significant ($p \leq 0.05$) difference in their emergence percentage at both sites. This agrees with the findings of Keter *et al (2009)* who worked on soybean fertility requirements. This could be due to inherent characteristics of soybean plant which is tolerant to poor soil fertility.The period between seeding and emergence was too short to observe a clear difference in the emergency using the varying fertilizer rates. The varieties did not indicate any differences in emergence percentage.This confirms the findings of George *el al (2003)* that the three varieties Sable, Gazelle and SB 19 take an equal percentage of days to emergence

5.2 Effect of sympal fertilizer rates and varieties on days to 50% flowering.

The lack of statistical of statistical difference in the experiment amongst the different sympal fertilizer rates (0 kg/ha, 200 kg/ha and 400 kg/ha) are consistent with what Kolol *et al (2009)* found out on soybean crop. That efficiency in flowering of soybean crop does not entirely depend on crop nutrient status, but rather on other biotic and abiotic factors, which affect the physiological status of the crop and eventual response of plant to growth and development. The results also showed that there was no significant difference in the varietal level of flowering. This is consistence with what George et al (2003) found out, (Table 1 page 18), that the above three varieties (Sable,Gazelle and SB 19) share the characteristic of having an equal number of days to flowering.

5.3 Effect of Sympal fertilizer rates and varieties on number of pods/plant.

Lack of statistical difference in the experiment amongst the sympal fertilizer rates is consistent with what Hemal *et al (2010)* found out about soybean crop tolerance to adverse environmental conditions. This showed that pod formation in soybean is mainly dependent on It's inherent capability, and to a lesser extent on the prevailing environmental conditions. The results also showed that, there was no significant difference in the varietal reponse to number of pods per plant.This is contradicting George *et al (2003)*. (Table1 page 18), Who found out that the above soybean varieties (Sable, Gazelle and SB 19) differed in the number of pods per plant

5.4 Effect of Sympal fertilizer rates and varieties on plant height.

The lack of statistical significant difference amongst the three varieties is very consistent with what Swaleh *et al (2009)* found out that soybean is one of the legume crops that can produce sustainable yields under adverse environmental conditions. The three soybean varieties have an efficient water uptake root system Gagehe *et al (2002).* There was also no significant difference as pertains the varieties. This could have been attributed to similar to similar inherent characteristics found in the three soybean varieties.

5.5 Effect of sympal fertilizer rates and varieties on 1000 grain weight

The lack of statistical significant difference amongst the three varieties is very consistent with what Swaleh et al (2009) found out that soybean is one of the legume crops that can produce. Sustainable yields under adverse environmental conditions.All soybean varieties have an efficient water up take root system Gagehe *et al (2002).*

The lack of significance may have been attributed to water content imbibed by the seed at the physiological maturity stage. There was also no significant differences in the varieties.

5.6 Effect of sympal fertilizer rates and varieties on grain yield.

Experimental findings indicate that sympal rates of 200 kg/ha were significantly ($p \leq 0.05$) superior to 0 kg/ha and 400 kg/ha at both sites. This might have been due to adequate supply of nutrients (Phosphorus at 46 kg/ha in combination with other macronutrients such as potassium magnesium and sulfur. This is consistent with what Wafula and Wengo (2008) who found out that phosphorus levels of between 45 kg /ha to 50 kg/ha combined with additional elements enhance the physiological processes and morphological set up of the soybean plant leading to increased crop yields.

The sympal fertilizer rate of 0 kg /ha registered a significantly ($P \leq 0.05$) inferior difference by realizing the lowest yields.This confirms the findings of Chianu *et al (2002)* about the importance of improved soil fertility for increased legume production.

From the study, SB 19 was significantly superior to Sable and Gazelle varieties. This confirms the results of Wafula et al (2010) in western Kenya of soybean varietal selections for increased crop yields.

5.7 Interaction between sympal fertilizer rates and varieties on grain yield.

The findings of the study showed that the interaction of sympal rates of 200 kg/ha (which supplied up tp 46 kg/ha of phosphorus and 32 kg/ha of potassium) in combination with variety SB 19 was significantly ($P \leq 0.05$) superior to the other interactions. It had the highest mean yield of 5.8 t/ha. This contradicts George *et al (2008)*who mentioned that SB 19 has a potential optimum production level of 5.3 t /ha.This also contradicts Swleh et al (2009) who found out that Gazelle variety is the best performing variety under acidic conditions.This conforms with Wafula *et al (2003)* who found out that the highest grain yield in western region has been achieved by application of phosphorus at rates of 45 kg/ha to 50 kg/ha in combination with other macro and micro nutrients. This was supported by Ogot et al (2005) who found similar results in soybeans. This may have been due to increased nutrient uptake and utilization by the soybean crop, due to increased levels of other macro and micro nutrients, which supported growth and development of the soybean plant.

This study showed that the use of high rates of sympal fertilizer at the of 400 kg/ha combined with the local variety (Sable) impacted negatively on the final soybean yields with a mean yield of 2.0 t/ha. The low mean yield of produced by sympal fertilizer rate of 400 kg/ha in combination with the local variety may have been because of nutrient toxicity to the plant.This might have impaired the physiological activities of the plant, which eventually may have affected growth and development of the soybean crop.

The interaction level one of sympal fertilizer rate of 200 kg/ha with the local variety (Sable) was also significantly ($P \leq 0.05$) inferior to other interactions with a mean yield of 2.0 t/ha at both sites.This conforms to Munyu et al (2000). The low yields may have been attributed to poor inherent characteristics possessed by the local variety which therefore renders it unproductive under acidic soil conditions.

CHAPTER SIX

CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

i) Planting soybean using sympal fertilizer produces high grain yield

ii) The genotype SB19 is adaptable and gives high grain yields while the local variety Sable gives low grain yields and is not adaptable

iii) Soybean yield can be maximized when the interactions of inorganic fertilizers are adopted by relative to farmers practice

6.2 Overall recommendations

i) Farmers in Bungoma and Kakamega should use Sympal fertilizer at the rate of 200 kg/ha

ii) It is worthwhile for farmers to adopt SB 19 variety for improved performance.

iii) Further research is required to find out the relationship between the environment and performance of soybean varieties (Sable, Gazelle and SB 19)

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APPENDICES

Appendix Ia: ANOVA for effects of treatments on emergence percentage – Site 1 (Bungoma)

Sources of variation	df	ss	ms	F value	P> F
Block	2	0.3333	0.1667	0.4000	0.3045
Variety	2	8.1667	4.0834	9.7993	. 0.3123
Sympal	2	1.5000	0.7500	1.7999	0.4001
Variety*Sympal	4	0.6667	0.1667	0.4000	0.1923
Error	16	6.6666	0.4167		
Total	26	17.3333..			. ..

R – Square (counts)	CoeffVar	Root MSE	Emergence % Mean
0.9	10.9	0.3	76.1

Appendix I b: ANOVA for effects of treatments on emergence percentage – Site 2 (Kakamega)

Sources of variation	df	ss	ms	F value	P> F
.					
Block	2	5.0830	2.5415	2.9576	0.3145
Variety	2	18.375	9.1875	10.6918	0.3223
Sympal	2	18.375	9.1875	10.6918	0.4001
Variety*Sympal	4	3.3750	0.8438	0.9819	0.2923
Error	16	13.750	0.8593		
Total	26	58.958		.	.

R – Square (counts)	CoeffVar	Root MSE	Germination % Mean
0.8	15.9	0.9	78.5

Appendix II a: ANOVA for effects of treatments on days to 50% percentage flowering – Site 1 (Bungoma)

Sources of variation	df	ss	ms	F value	P> F
Block	2	20.833	10.4165	9.5582	0.3081
Variety	2	3.3750	1.6875	1.5484	0.3002
Sympal	2	10.417	5.2085	4.7793	0.4447
Variety*Sympal	4	20.417	5.1043	4.6837	0.1925
Error	16	17.4366	1.0898		
Total	26	72.4786			

.	R – Square	Coeff Var	Root MSE
50% flowering Mean (counts)	0.464	11.0	1

Appendix II b: ANOVA for effects of days to 50% flowering – Site 2 (Kakamega)

Sources of variation	df	ss	ms	F value	P> F
Block	2	7.5833	3.7917	1.0722	0.4611
Variety	2	3.3750	1.6875	0.4772	0.3400
Sympal	2	15.0417	7.5209	2.1267	0.0558
Variety*Sympal	4	3.3750	0.8438	0.2386	0.6468
Error	16	56.5833	3.5365		
Total	26	85.9583			

R – Square	CoeffVar	Root MSE	50% flowering Mean (counts)
0.4	22.4	1.9	75

Appendix I11 a: ANOVA for effects of treatments on plant height – Site 1 (Bungoma)

Sources of variation	df	ss	ms	Fvalue	P> F
Block	2	80.6812	40.3406	5.9234	0.2510
Variety	2	162.760	81.3800	11.9494	0.3960
Sympal	2	508.760	254.380	37.3517	0.4500
Variety*Sympal	4	0.0104	0.0026	0.0000	0.5000
Error	16	108.967	6.8104		
Total	26	861.118			.

.R – Square	CoeffVar	Root MSE	Plant height Mean (cm)
0.9	4.8	4.3	62

Appendix I11 b: ANOVA for effects of treatments on plant height – Site 2 (Kakamega)

Sources of variation	df	ss	ms	F value	P> F
Block	2	18.3958	9.1979	0.2148	0.2610
Variety	2	276.7604	138.380	3.2315	0.3860
Sympal	2	956.3438	478.1719	11.1666	0.4600
Variety*Sympal	4	41.3438	103.359	2.4137	0.5000
Error	16	685.1458	42.8216		
Total			26		1977.9896

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.R – Square	Coeff Var	Root MSE	Plant height	Mean (cm)
0.8	6.1		5.0	56. 2

Appendix 1Va: ANOVA for effects of treatments on Number of pods per plant Site 1 (Bungoma)

Sources of variation	df	ss	ms	F value	P> F. .
Block	2	18.2058	9.1029	4.2983	0.0164
Variety	2	0.4817	0.24085	0.1137	0.5952
Sympal	2	6.4067	3.2034	1.5126	2.4010
Variety*Sympal	4	0.0150	0.0038	1.7943	0.8249
Error	16	33.884	2.1178		
Total	26	58.9932			. .

R –Square	Coeff Var	Root MSE	Number of pods (counts)
0.8	6.1	1.3	37

Appendix 1V b: Effect ANOVA for effects of treatments Number of pods per plant Site 2 (Kakamega)

Sources of variation	df	ss	ms	F value	P> F
Block	2	8.1258	4.0629	3.9289	0.2114
Variety	2	2.2817	1.1409	1.1032	0.3397
Sympal	2	5.4150	2.7075	2.6182	0.2501
Variety*Sympal	4	0.3267	0.0817	0.0790	0.6140
Error	16	16.545	1.0341		
Total	26	32.6942			.

R – Square	CoeffVar	Root MSE	Number of pods Mean (counts)
0.9	5.9	1.2	38

Appendix V a: ANOVA for effects of treatments on 1000grain weight Site 1 (Bungoma)

Sources of variation	df	ss	ms	F value	P> F
Block	2	1.6300	0.8150	0.677	0.2093
Variety	2	2.8017	1.4009	1.1634	0.0558
Sympal	2	2.5350	1.2675	1.0527	0.0561
Variety*Sympal	4	0.0017	0.0004	0.0003	0.8600
Error	16	19.266	1.2041		
Total				26	26.2344

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R – Square	Coeff Var	Root MSE	1000 grain weight Mean (g)
0.7	2.8	0.8	83.1

Appendix V b: ANOVA for effects of treatments on 1000grain weight Site 2 (Kakamega)

Sources of variation	df	ss	ms	F value	P> F
Block	2	4.480	2.2400	1.1684	0.2619
Variety	2	22.426	11.210	5.8474	0.0552
Sympal	2	3.526	1.7630	0.9196	0.1105
Variety*Sympal	4	0.240	0.060	0.000	0.7432
Error	16	30.6734	1.9171		
Total	26	61.3454	.		

R – Square	CoeffVar	Root MSE	1000 grain weight Mean (kg)
0.5	5.2	1.4	88.8

Appendix VI a: ANOVA for effect of treatments on grain yield - site 1 (Bungoma)

Sources of variation	df	ss	ms	F value	P> F
Block	2	1.9823	0.9912	0.7870	0.2962
Variety	2	3.6353	1.8177	1.4433	0.0007
Sympal	2	8.6760	4.338	3.4446	0.0050
Variety*Sympal	4	2.3250	0.5813	0.4616	< 0.0001
Error	16	20.150	1.2594		
Total	26	36,7686			

R – Square	CoeffVar	Root MSE	Grain yield Mean (tons per ha)
0.8	20.4	0.9	4.2

Appendix VII b: ANOVA for effect of treatments on grain yield Site 2 (Kakamega)

Sources of variation	df	ss	ms	F value	P>F
Block	2	4.2893	2.1447	2.2308	0.0015
Variety	2	6.0803	3.0402	3.1623	< 0.000
Sympal	2	3.0628	1.5314	1.5929	< 0.000
Variety*Sympal	4	1.4603	0.3651	0.3798	0.00025
Error	16	15.3827	0.9614		
Total	26	30.2754			.

. R – Square	CoeffVar	Root MSE	Grain yield Mean (tons/ha)
0.95	10.8	0.4	4.2