EVALUATING THE EFFECTS OF COBALT/MOLYBDENUM, RHIZOBIUM INOCULANTS AND DIAMMONIUM PHOSPHATE FERTILIZER ON THE GROWTH AND YIELD OF SOYA BEANS IN KISII COUNTY

DORICE OMBUNA OMWOCHA

A Research Thesis Submitted to the School of Science and Technology in Partial Fulfilment of the Requirements for the Conferment of Degree of Master of Science in Agricultural and Rural Development of Kenya Methodist University

AUGUST, 2020

DECLARATION AND RECOMMENDATIONS

DECLARATION

This thesis is my original work and has not been presented for award of a degree in any other University.

Signed………………………Date……8/8/2020………………………

Dorice O. Omwocha (AGRI-3-8024-1/ 2014)

RECOMMENDATION

This thesis has been submitted for examination with our approval as University supervisors

Signed………………………… **Date…………8/8/2020…………………………………**

Dr. Mworia Mugambi, Ph.D.

Kenya Methodist University

Signed………………………… **Date……8/8/2020……………………………….**

Dr. John. M. Muchiri, Ph.D.

Kenya Methodist University

COPYRIGHT

DEDICATION

To my late parents, Wycliffe and Margaret, late husband Gilbert Mokaya and children Ian, Sally and Isaac. For their love support and encouragement in my education.

ACKNOWLEDGEMENT

I thank God for the gift of life, good health and wisdom for this achievement. I am thankful to my supervisors, Dr. Mugambi Mworia and Dr. John Muchiri for their invaluable guidance, patience and constructive criticisms throughout my research work.

I am sincerely indebted to Dr. David Mushimiyimana and Dr. Johnson Kwach of KALRO-Kisii, for their valuable suggestions on this thesis. My gratitude goes to Mr. Benson Mulei (Deputy Director Crops), Mr. Ibrahim Bunge and Kisii Agricultural Training Centre staff for their relentless support. I would also like to thank Mr. Iracha of Bayer Company, for availing the seed and the inoculants for the study. May God bless you!

My sincere appreciation's goes to Kenya Methodist University for giving me the opportunity to pursue my postgraduate studies, KALRO Kisii, Crop Nuts, Bayer Company and Kisii Agricultural Training Centre for the immense support towards the accomplishment of my research. I am deeply indebted.

ABSTRACT

Soya bean is an important crop grown globally. It is the main source of dietary protein and oil and is used commercially to produce livestock feed and food for humans as well. Soy farming is mostly practised in the western and central regions of Kenya but the yield is low compared to other countries. Production is low in Kisii yet the potential for optimum yield is documented. Poor soya bean yield is thought to be caused by infertile soils due to poor agronomic and management practices, acidified soil, deficient nutrients in the soil and use of unimproved seed varieties. The study evaluated the effects of cobalt/molybdenum, rhizobium inoculants and diammonium phosphate fertilizer on the growth and yield of soya beans in Kisii County. A randomised complete block design experiment replicated in four blocks was done at Kisii Agricultural Training Centre.Treatments used for seed dressing per kg/seed included: Rhizoliq Top Soya 3mls, Wuxal Extra CoMo15 at 1ml, Wuxal Extra CoMo 15 at 1.5 mls, (Wuxal Extra CoMo 15 at 1.5 mls / Rhilizic top 3mls) and (Waxul Extra15 CoMo1m/Rhizoliq top 3ml, Control (Without Treatments), DAP 125kg/ha^{-1}, of soya seed. Analysis of variance was conducted using SPSS version 22 and any significant means were further analysed using DMRT all at 95% confidence level. Soil analysis revealed moderately acidic soil (pH 5.5) low nitrogen (0.12%), moderate Phosphorus (20ppm) and low potassium levels (40%). Cobalt was 54.6 and Mo 6.44 Mg/lg. On germination CoMo1ml+Rhizob yielded the highest percentage, followed by CoMo1.5ml, with a significant statistical difference between treatments (< 0.05). CoMo1ml+ Rhizobium had the highest flowering percentage. Above ground biomass was highest with the use of CoMo1.5ml/ Rhizobium. CoMo1ml/ Rhizobium treatment showed highest pod weight per plant and had a statistically significant difference (<0.05). On the six plants seed weight per plant, Rhizobium treatment exhibited highest weight whereas the least was CoMo1ml. CoMo1.5ml/Rhizob was shown to have the highest 100 seeds weight, with statistically significant difference among the treatments (<0.001). The highest yielding inoculant was CoMo1ml/Rhizob followed closely by Rhizob. ANOVA showed a strong significant difference among the treatment's yield per ha (<0.006). Plant height was highest with CoMo1ml, ANOVA exhibited a significant difference among treatments (<0.001). CoMo1ml/Rhizob exhibited the heaviest weight of seeds with the least weight from the control and CoMo1ml respectively. Where the inoculants were combined at different graded levels, favourable effects on all growth and yield parameters were exhibited. CoMo 1ml+Rhizob exhibited most positive effects. The study concluded that low yield in Kisii and other soya bean growing zones in Kenya can be enhanced by use of combined selected inoculants.

TABLE OF CONTENTS

DECLARATION AND RECOMMENDATIONS...ii

COPYRIGHT iii

DEDICATION...iv

ACKNOWLEDGEMENT...v

ABSTRACT...vi

LIST OF TABLES..x

LIST OF FIGURES...xii

ABBREVIATION AND ACRONYMS...xiii

CHAPTER ONE..11

INTRODUCTION...11
1.1 Background of the Study 11
1.2 Statement of the Problem 20
1.3 General Objective of the Study...21
1.4 Specific Objectives..21
1.5 Research Hypothesis 21
1.6 Justification of the study...21

CHAPTER TWO...23

LITERATURE REVIEW 23
2.1 Introduction...23
2.2 Botany of soya beans...23
2.3 Ecological conditions of soya beans 24
2.4 Agronomic aspects of soya beans value chain..26
2.5 Nutritional value of soya beans...28
2.6 Soya beans production..28
2.7 The role of nitrogen on growth and seed yield of soya beans 32

2.8 Effect of di-ammonium phosphate fertilizer, molybdenum, cobalt and rhizobium inoculants on the growth and yield of soya beans. 34

CHAPTER THREE 47

RESEARCH METHODOLOGY 47
3.0. Introduction. 47
3.1. Study Site Description 47
3.2 Experimental research design 48
3.3 Treatments and treatment combinations 48
3.4 Experimental layout 48
3.5 Land preparation and planting 49
3.6 Data collection procedures 50
3.7 Data management and analysis 51

CHAPTER FOUR 53

RESULTS AND DISCUSSION 53
4.0 Introduction. 53
4.1 Effects of different levels of cobalt/molybdenum, rhizobium inoculants and diammonium phosphate fertilizer on germination percentage. 53
4.2 Effects of different levels of cobalt/molybdenum, rhizobium inoculants and diammonium phosphate fertilizer on flowering percentage 56
4.3 Effects of different levels of cobalt/molybdenum, rhizobium inoculants and diammonium phosphate fertilizer on above ground biomass 57
4.4 Effects of different levels of cobalt/molybdenum, rhizobium inoculants and diammonium phosphate fertilizer on six plants pod weight 59
4.5 Effects of different levels of cobalt/molybdenum, rhizobium inoculants and diammonium phosphate fertilizer on six plants seed weight 61
4.6 Effects of different levels of cobalt/molybdenum, rhizobium inoculants and diammonium phosphate fertilizer on 100 seeds weight 64
4.7 Effects of different levels of cobalt/molybdenum, rhizobium inoculants and diammonium phosphate fertilizer on yield in kg per ha. 67
4.8 Effects of different levels of cobalt/molybdenum, rhizobium inoculants and diammonium phosphate fertilizer on number of branches at harvest 70
4.9 Effects of different levels of cobalt/molybdenum, rhizobium inoculants and diammonium phosphate fertilizer on number of pods at harvest 71
4.10 Effects of different levels of cobalt/molybdenum, rhizobium inoculants and diammonium phosphate fertilizer on plant height at harvest 72
4.11 Effects of different levels of cobalt/molybdenum, rhizobium inoculants and diammonium phosphate fertilizer on number of leaves at maturity 74
4.12 Effects of different levels of cobalt/molybdenum, rhizobium inoculants and diammonium phosphate fertilizer on weight of seeds the whole plot 76

CHAPTER FIVE 79

SUMMARY, CONCLUSIONS AND RECOMMENDATION 79
5.1Introduction.. 79
5.2 Summary of the findings 79
5.3 Conclusions.. 80
5.4 Recommendation.. 81
5.5 Research output.. 81

REFERENCE 83

APPENDICES 96

LIST OF TABLES

Table 2. 1 Varieties of soybeans grown in Kenya 27

Table 3.2 Experimental layout in Randomized Complete Block Design (RCBD) 49

Table 4. 3 ANOVA on the effect of inoculants on germination percentage 54

Table 4.4 DMRT for germination percentage 55

Table 4. 5 ANOVA on the effect of inoculants on flowering percentage...................... 56

Table 4.6 ANOVA on the effect of inoculants on above ground biomass. 58

Table 4.7 ANOVA on the effect of inoculants on pod weight 60

Table 4.8 DMRT for pod weight per plant.. 60

Table 4. 9 ANOVA on the effect of inoculants on seed weight per six plants 63

Table 4.10 ANOVA on the effect of inoculants on 100 seed weight in grams.............. 65

Table 4.11 DMRT Comparison of 100 seed weight in grams under different treatments 66

Table 4.12 ANOVA on the effect of inoculants on yields kg ha................................... 68

Table 4.13 DMRT for grain yield in kilograms per ha 69

Table 4. 14 ANOVA on the effect of inoculants on number of branches at harvest...... 70

Table 4.15 ANOVA on the effect of inoculants on the number pods at harvest............ 71

Table 4.16 ANOVA on the effect of inoculants on plant height at harvest. 73

Table 4. 17 DMRT for height of plants at harvest.. 73

Table 4.18 ANOVA on the effect of inoculants on number of leaves at harvest........... 75

Table 4.19 ANOVA on the effect of inoculants on weight of seeds whole plot............ 77

Table 4.20 DMRT for weight of seed the whole plot. 77

LIST OF FIGURES

Figure 4.1 Mean germination percentage. 54

Figure 4.2 The mean weight of pods in grams per plant 59

Figure 4.3 Mean six plants seed weight.. 62

Figure 4.4 Mean weight of 100 seed weight 64

Figure 4.5 Mean yields in kilograms hectare 67

Figure 4.6 Mean plant height at harvest.. 73

Figure 4.7 Weight of seed whole plot 76

ABBREVIATION AND ACRONYMS

ANOVA	:	Analysis of variance
BNF	:	Biological nitrogen fixation
CO	:	Cobalt
COMO	:	Cobalt and molybdenum
CI	:	Confidence Interval
CV	:	Coefficient of variance
FAO	:	Food and Agricultural Organisation
GOK	:	Government of Kenya
IITA	:	International Institute of Tropical Agriculture
ISFM	:	Integrated Soil Fertility Management
KALRO	:	Kenya Agricultural and Livestock Research Organization
KATC	:	Kisii Agricultural Training Centre
LSD	:	Least Significance Difference
MO	:	Molybdenum
MOA	:	Ministry of Agriculture
N	:	Nitrogen
NPK	:	Nitrogen, Phosphorous, Potassium
RHIZILIQ	:	Rhizobium
RI	:	Rhizobium inoculants
SPSS	:	Statistical Package for Social Scientists (and service solution)
SSA	:	Sub- Saharan Africa

USDA	:	United States Department of Agriculture
UTC	:	Untreated Check
Zn	:	Zinc

CHAPTER ONE

INTRODUCTION

1.1 Background of the Study

Soya bean is a popular leguminous plant grown worldwide (FAO, 2018). According to plant database, soybean is a dicotyledonous fabaceae; the genus is the soybean and described to be *Glycine max* (L.) Merr. Species (United States Department of Agriculture [USDA], 2020). Soya beans alongside other grain legumes grow in diverse environmental conditions. It is recognized to be a rich in oil and protein hence widely utilized for human consumption in addition to its use as animal fodder. Protein content in soya beans is as high as 35-40%, contributing 58% to the world's oil seed production. It is a valuable cash crop in the manufacturing industry (Ohyama et. al., 2017).

According to Ohyama et al.(2017), the main soybean generating countries in 2013 included United States of America (USA) producing 89.5 Million tons annually, followed by Brazil that generated 81.7 Million tons, Argentina produced 49.3 Million tons, China and India's' output was 12.5 and 12.0 Million tons respectfully. Further, Japan generated 200,000 tons, which is only 8% of what Japan consumes annually. The amount of produce by the United States of America and India is reported to have been gradually increasing in the last 30 years, but China suffered a decrease between the years 2003 to 2013. By 2013, the estimated global production was 2.48 tons per hectare, but the top producers like the USA produced higher at 2.91 tons per hectare, Brazil 2.93 tons per hectare, Argentina 2.54 tons per hectare, Paraguay 2.95 tons per hectare and Canada

2.86 tons per hectare. Lower yield was reported from China 1.89 tons per hectare, Japan 1.55 tons per hectare and India 0.98 tons per hectare

Globally in the 2017/2018 crop season, production of soya beans was reported to approximately 346.9 million mega grams per hectare. Historically, soybeans originated from East Asia, the largest producers currently are the United States of America (USA), Brazil, India and Argentina, contributing 82% of total world production (Cordeiro & Echer, 2019). In East Africa, Kenya is the lowest soya producers in East Africa (Gikonyo et al., 2014a; Mathenge et al., 2019); the production is 1500 to 3000 tons annually. The domestic consumption of soybean is reported to be 150,000 tons, creating a deficit leads to increased importation so as to supplement local production. (FAOSTAT, 2019).

In 2018, Kenya imported 68,000 tons of soy meal; this figure had tripled in 10 years (Mundi 2019). Kenya also spent USD 12.8 million on importation of soy oil alone in 2016 (FAOSTAT 2019). In Kenya, cultivation of soya beans is practiced in the maize growing zones like the Rift valley by small scale h growers. It is gown mainly in the western region, especially in Kakamega, Vihiga, Busia, Bungoma, Transnzoia, Siaya, Homabay, Migori, Kisii and Nyamira counties. It's also grown in the Central and Mt. Kenya highland region comprising Kirinyaga, Embu, Meru and Tharaka Nithi Counties (Mathenge et al., 2019b). There is paucity of actual data on the yield and productivity of soya bean in Kisii County.

The agricultural sector in Kenya is responsible for satisfying the increasing demand from her growing population. Soybeans for animal feed and dietary protein consumption due to the increasing appetite for protein products are a top priority in the country (Foyer et al., 2019). To meet this demand, the government included the soya bean crop as part of its vision 2030 under the economic pillar was recognized as an important economically viable and sustainable crop (GoK, 2007).

Even though the production of soybeans is reported to be low in Sub-Saharan Africa, the potential of this variety of legume is high. The yield can be as high as four to six tons per hectare with proper agricultural land practices under a wide range of good environmental and soil conditions. Soybean production potential is the top most production of seeds cultivated in a favourable ecological zone, where the nutrients and water are adequate, as wells as vermin and diseases are prevented. The potential of soybean was demonstrated by Mr. Kip Cullers from the USA, he recorded production as high as 10 tons per hectare. This demonstrates that soya bean potential is much higher than is assumed. Potential soya bean potential is estimated to vary between 6–8 t ha−1 in the USA corn-belt region (Ohyama et al., 2017). Kenya has the potential to produce more soybeans yield, the region as varying altitude (0 to 2200m) above sea level, rainfall between 300 to 1200 mm per annum and a pH is between 6 to 6.5, which provides a conducive environment for the crop to grow (Mathenge et al., 2019b).

More than thirty-nine percent (39%) of children below the age of five are malnourished with have stunted growth. It is associated with lack of critical protein micronutrients almost all food (Assenga et al., 2016). Protein malnutrition has resulted to over one third of childhood mortalities in Kenya (Lobo et al., 2019). Capitalizing on soya bean farming in Kenya's smallholder farming systems would go a long way in boosting nutrition, decreasing mortality and morbidities, as well as enhancing integrated soil fertility. The value of soya beans can only occur if proper farming practices and soil fertility management are emphasized while farming (Sylvain, 2020).

Globally, discrepancies in soybean production is linked to a myriad of constraints besides other abiotic and socio-economic factors cutting through various areas in sub-Saharan Africa (SSA) (Argaw, 2016; Cordeiro & Echer, 2019; Gikonyo et al., 2014a). In western Kenya, low productivity is attributed to low soil fertility and acid soils (Mathenge et al., 2019b). Use of applications that farmers globally have leveraged on besides the normal fertilizer regularly used is seen as an effective way to boost productivity in Kenya.

More than 80% of soils in in Sub-Saharan Africa (SSA) are documented to be low in nitrogen levels (Mathenge et al., 2019). According to (Ferri et al., 2017), Nitrogen (N) is an indispensable plant nutrient related to that is link to the growth of legumes. Besides other micronutrients, nitrogen in soybean production is very important and usually accounts for 1 to 5% of crop dry matter. Averagely, for every one tonne of yield, it is estimated that eighty kilograms of nitrogen micronutrient is required by the crops (Hankinson et al., 2015; Hc & Aa, 2019). Availability of nitrogen balance influences root and shoot development and photosynthesis, in which the division of energy in the whole plant causes optimal growth (Lacerda et al., 2017).

Additionally, other micronutrients reported to be deficient in soil besides nitrogen include, phosphorous (P) and organic matter, and soils are also acidity (Argaw, 2016; Asante et al., 2020) , nitrogen (N). This factors have to be improved as they are vital in the interaction of the legume, rhizobia strain, ecosystem, and crop management, which subsequently influence biological nitrogen fixation (BNF) and plant yield (Gibson et al., 1982; Woomer et al., 2014; Keino et al., 2015; Thuita et al., 2018).

Most of the farmlands in Africa is reported to contain very little organic carbon resulting from competition from utilization of organic residues (Cordeiro & Echer, 2019; Gikonyo et al., 2014b; Mathenge et al., 2019b). Availability of organic carbon is essential in soil fertility, deficiency of this element below the critical level in soil could affect the performance of other non-limiting factors (As et al., 2017a). However, addition of organic matter into soil could improve the action of inorganic fertilizers (Singh &Ryan, 2015).

Application of phosphorus in legume production has been emphasized by many projects that work to promote rhizobia inoculation in Africa. Many other previous projects conducted have endorsed use of phosphorus in boosting production. Now days, balanced fertilizer mixtures without nitrogen been developed and can be used alongside inoculant (As et al., 2017a; Ibrahim Dagash, 2015; Meena et al., 2018). Scientific researches indicate that soya beans do not respond well in very low PH and acidified soils, therefore, liming is recommended to increase the PH to 6.0 or 6.5 for best yield production (Oliveira, et al., 2018).

Physical and chemical elements from plants are important in enhancing integrated soil fertility management (Alam, Kim, et al., 2015; Asei et al., 2015; Hc & Aa, 2019). The harvested plants residues when tilled back into the soil, enriches it with quality organic matter that has well balanced beneficial C: N ratio. Soya beans for instance, improve soil productivity by converting nitrogen available in the air (Alam, Kim, et al., 2015; Mathenge et al., 2019b; Meena et al., 2018). Some soya varieties can fix from 44 to 103 kg of nitrogen per hectare annually into the soil (Sanginga *et al.*, 2003). Legumes are highly recommended in low soil fertility zones (Santos et al., 2019). Overall, biological nitrogen fixation (BNF) ability of leguminous plants is an important agronomic practice (Ulzen et al., 2016b)

Brazil is among the top soybean producer (USDA, 2016), is associated with the use of bacterial inoculants (*Bradyrhizobium*), the bacteria acts by transforming nitrogen absorbed from the air into ammonia ions (NH4) by adding hydrogen, it is thereafter absorbed by crop tissues as nitrogenous compounds. Such beneficial relationship between rhizobium and crops is crucial in the growth and development of legumes (Araujo et al., 2017; Santos et al., 2019). Additionally, *bradyrhizobium* spp. application in Brazil during sowing or soil fertilization process is done either by spraying or when planting seeds prior to planting, both methods can be done concurrently (Neto et al., 2017). A high level of Nitrogen is important in soya beans because of their high protein content.

Availability of the required nitogen is normally through nitrogen fixation. Nitrogen is an important element of yield, its most often a regulating factor in attaining the best yields (Araujo et al., 2017). Nitrogen fertilization has its own uniqueness; mineral nitrogen which is the form available for plants is liable to diminish as a result of leaching and movement in the soil as well as during the reduction of nitrate and nitrite to gaseous nitrogen. In view of this, farmers can capitalise on adding organic matter in the soil however, nitrogen converting bacteria is non effective in acidified soils (< 4.2), the recommended pH range is 6 to 6.5 for ideal soya beans growth (Meena et al., 2018).

Use of inoculants such as *brady rhizobium japonicum, bradyrhizo-biumelkani and Sino rhizobium fredi* is known to produce root nitrogen fixing nodules (Cordeiro & Echer, 2019). Due to the limited availability of *Bradyrhizobium* in agricultural soils, application in the form of bacterial preparation is recommended when planting soya beans. Use of microbial fertilizers significantly affect growth, development and productivity of soya beans (Lobo et al., 2019). Inoculation process is recommended when the amount of rhizobia is really low, supplying capacity, low nutrient absorption capacity, low organic matter, presence of leaching and high acidity levels in soil (Crusciol et al., 2019; Etopobong, 2017; Kubota et al., 2008; S., 2014).

Cobalt is also key and is highly recommended although there is no direct correlation of the role played in metabolism of plants (Filho et al., 2017). It is documented that cobalt plays a role in fixing atmospheric nitrogen, and the deficiency of cobalt seems to reduce the efficiency of Nitrogen fixation (Filho et al., 2017; Ulzen et al., 2016a). In many research studies, molybdenum was also found to be an important and mandatory element for fixing nitrogen in the air. It acts by reducing the quantity of root nodules and also increases the dimensions plus physiological activity resulting in greater nitrogen fixation. Molybdenum is a constituent of the nitrate reductase enzyme, which helps in the converting nitrate to ammonium. Additionally, it plays a role as an element of nitrogenize, that aids in converting air nitrogen, however, plants need very minimal amount and so the molybdenum level in soils is as low as 2ppm (Alam et al., 2015; Crusciol et al., 2019)

The more acidic the soil is, the lower the level of molybdenum due to the iron and aluminium solubility in soil. When these elements react, Mo is depleted and subsequently soil pH is increased. Liming is adequate for sustainable molybdenum presences for all plants. Apart from sand, low amount of molybdenum can be found in aged soils. Molybdenum is assimilated in plants as themolybdate (MoO_4^-) ion, availability of increased levels of soil sulphate (S04) can diminish absorption (Meena et al., 2018; Neto et al., 2017; Pedrozo, Girelli de Oliveira, et al., 2018). Some of the signs in plants that are indicative of deficiency include; light yellow green leaves initially, but in chronic situations the leaf edges change to brown and curl upward, known as cupping (Alam, Kim, et al., 2015). Nevertheless, molybdenum deficiency not common but no reliable soil analysis has ever been established to test its availability in soil (Asei et al., 2015).

According to Sylvain, (2020), improved agronomic practices has been occasioned by biological nitrogen fixation (BNF) through use of developed rhizobia inoculants. The demand for high nitrogen by soybeans can be obtained from biological nitrogen fixation (Sylvain, 2020). Some studies have demonstrated that, the use of 50 kg of nitrogen per hectare improved the growth and yield of plants such as: height, pods count, dry pods mass and total yield, higher compared to application of 200 kg nitrogen per hectare in un inoculated seeds (Kang, 2020).

Use of combined strains of inoculants in several studies is noted to be more effective than single strains. Two strains increases the probability of better fixation than one strain would in legumes (Alam, Kim, et al., 2015; Asante et al., 2020; Ibrahim Dagash, 2015). In Brazil for instance, use of two *Bradyrhizobium* strains in soybean cultivation has been a norm since the 1950s (Araujo et al., 2017). Currently, the idea of combined use of inoculants has spread because it is evident that it results to more yield. (As et al., 2017a; Asante et al., 2020; Meena et al., 2018; Pedrozo, Oliveira, et al., 2018).

Examples of mixed inoculant whose major mechanism is through BNF include: *Bradyrhizobium* spp., *Rhizobium* spp.; phytohormone (e.g. *Azospirillum* spp., *Pseudomonas* spp.), solubilization of phosphate (e.g. *Bacillus* spp.), or biological control (e.g. *Pseudomonas* spp., *Bacillus* spp.). The products available in the market are either combined bacteria products or singly (Filho et al., 2017; Rechiatu et al., 2015). Mixed inoculants are also referred to as co-inoculation or mixed inoculation (Ferri et al., 2017; Meena et al., 2018). The effectiveness of mixed inoculants is so much linked to; correct selection of bacteria strains, cellular concentration, inoculation procedure, and the crop type (Hc & Aa, 2019).

Soya beans are cultivated in Kisii County ranging from the hill slopes to the relatively flat zones. Low productivity is linked to poor agronomic and management practices, deficient nitrogen and phosphorus nutrients in soil, acidified soil and unimproved seed types. Moreover, inoculants are expensive smallholder farmers (Alam et al., 2015). Yield could be improved using BNF technology that enhances soil fertility by increasing

N fixation (Kang, 2020). Additionally, integrated soil fertility management using soya beans is also sustainable for smallholder agriculture (Mathenge et al., 2019).

Cultivation of soybean seeds with high BNF capability through use of inoculants could be a viable way to increase yield Kisii County and the country at large (Tahir et al., 2009). The study therefore, aimed to examine the effects of diammonium phosphate fertilizer, molybdenum, cobalt and rhizobium inoculants on the growth and yield of soya beans in Kisii County.

1.2 Statement of the Problem

Soya beans have considerable benefits for both animals and humans, but the production in Kenya is low. Small scale farmers in Kenya produce 0.3t -1 t/ha^{-1} while the potential can be 3 to 4 t/ha^{-1}.With proper agricultural land practices under a wide range of good environmental and soil conditions. Actual information on soya bean production in Kisii is unavailable but reported annual yield estimates in the western region of Kenya is low. The low production is thought to be due to poor soil fertility, poor agronomic practices coupled with the use of low yielding uncertified seeds. To meet the demand for local consumption of soya beans in Kenya, evidence based interventions have to be instituted in order to increase yield of soya beans. The study therefore evaluated effects of cobalt/molybdenum, rhizobium inoculants and diammonium phosphate fertilizer on the growth and yield of soya beans soya beans in Kisii County.

.

1.3 General Objective of the Study

To evaluate the effects of molybdenum/cobalt, rhizobium inoculants and diammonium phosphate fertilizer on the growth and yield of soya beans in Kisii County.

1.4 Specific Objectives

i. To assess the effects of cobalt/molybdenum inoculant on the growth and yield of soya beans.

ii. To analyse the effects of rhizobium inoculant on the growth and yield of soya beans.

iii. To evaluate the interaction of cobalt, molybdenum, rhizobium inoculants and diammonium super phosphate on the growth and yield of soya beans.

1.5 Research Hypothesis

i). Combination of cobalt and molybdenum inoculants significantly affects the growth and yield of soya beans

ii). Application of rhizobium inoculants significantly affects the growth and yield of soya beans

iii). Application of cobalt, molybdenum, rhizobium inoculants and diammonium super phosphate combination significantly affects the growth and yield of soya beans

1.6 Justification of the study

Soybeans remain vital for food security in Kenya. The growing population in Kenya calls for diversification to meet the increasing demand for affordable and nutritious protein giving food. Cultivation of soya beans using inoculants will increase the production as evidently shown in developed countries. Studies on the effect of nitrogen and phosphorous on soya beans is documented but little has been done on use of inoculants in Kisii.

Further, research using as rhizobium, cobalt and molybdenum to increase soya beans production in Kisii, soya bean-growing zone has not been done, yet evidence from previous studies show its positive effect on legume yield. The research results could be used to inform policy, educate farmers, agricultural extension officers, and the industry at large. Improved soya beans agricultural practices could increase bean yields in Kisii and other soybean growing zones in Kenya.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

This section includes extensively reviewed work on botany and ecology of soya beans, agronomic and nutritional importance of soya beans. The literature provided focused on soya beans, soya bean taxonomy, production from global and local perspective, further, and the role of nitrogen and phosphorous on growth and yield of soya beans was also reviewed. Lastly, influence of rhizobium, molybdenum and cobalt on the growth and yield of soya beans is discussed in depth. Literature search was done using databases such as Google Scholar, PubMed, Hinari among others. All the articles used in the review were current to ensure that the articles chosen and presented in this chapter were comparatively up-to-date of the current situation in regards to soya bean growth and production.

2.2 Botany of soya beans

Soya bean also referred to as soybean *(Glycine max (L.) Merr)* is a legume plant cultivated annually for its seeds. The taxonomy of soybean is described as, a flowering dicotyledonous plant belonging to the pea family; its genus is the soybean and *Glycine max* (L) Merr species (USDA, 2020). Food and Agricultural Organization (FAO) categorized it as oilseed and not a pulse. The upper plant is covered with fine brown or grey hairs. The leaves are trifoliate in nature, with three to four leaflets in a leaf, the length measure six to fifteen centimetres long and also two to seven centimetres wide 2-

7 cm (Mathenge et al., 2019b). Before the seeds are mature, the leaves go through abscission. The flowers are normally white, pink or purple in colour, they are also self-fertilizing. The pods develop in groups of three to five with individual being three to eight centimetres long, inside it has an average of two to four seeds (Lacerda et al., 2017). Soya beans differ in sizes with their exterior and seed coat colours ranging from black, brown, and blue, yellow, green to mottle. It propagates to as high as of sixty to one twenty centimetres long, and adopts well to diverse environments and matures in three to six months but dependent on seed type and ecological zone cultivated (Hc & Aa, 2019). Through the synergistic nitrogen fixation characteristic of legumes, soya beans can grow in diverse soils depending on regions (Foyer et al., 2019).

2.3 Ecological conditions of soya beans

Indigenous legumes grown Africa since time immemorial are the common bean**,** pigeon pea and cowpea, but currently, soybean is one of the five most important crops globally (Foyer et al, 2019). Soya beans is said to been domesticated across the world as it originated from East Asia 6000– 9000 years back (Mrkovacki et al., 2008). According to FAOSTAT, (2017), cultivation and yield of soya beans worldwide improved starting from 1961 to more than 340 million metric tons in the year 2016

Soya beans are cultivated within latitude of 55degN or 55degS, and an altitude of 2000 m (Info net, 2009). In Kenya where the altitude is from 0 to 2200m above sea level, the beans are main grown in maize producing zones by small-scale farmers practicing intercropping. The rainfall required for favourable cultivation is usually between 300 to 1200 mm per annum, while the pH is between 6 to 6.5 (Mathenge et al., 2019b). Kisii

County is characterised by 75% of red volcanic soils and much of it in the form of organic matter. The remaining part 25% is either clay soils that have very poor drainage red loams or sandy soils. Additionally, the basins base contains verisols and phanosols. The red volcanic soil is favourable for crops such tea, coffee, pyrethrum, maize, beans and potatoes. The ecological areas are divided into the upper midland which is 75%, Lower Highland is 20%, and Lower Midland 5%. Most part of the land in Kisii is covered with 57% of crops (Kisii County, 2019).

Soya bean thrives in warm climates that range from low to medium altitudes (21degC to 30 deg C). It is important to note that high altitude zones negatively affect the flowering and maturity of soybeans, high temperature affects the initiation of flowering. Such conditions render the plant to a vegetative state. (Cordeiro& Echer, 2019; Gikonyo et al. 2014b). For improvement of soil fertility, it is advisable to put the nitrogen from the atmosphere and preferably grow the crop in a pure stand(Alam et al., 2015; Hc & Aa, 2019; Pedrozo, Girelli de Oliveira, et al., 2018)**.**

The advantage of the soybean crop is that it is an annual crop, and as long water is available between 400 to 500 mm, crops can grow in both tropics and subtropics which is necessary during germination, flowering and pod forming stage. The beans mature and normally ripen through the dry weather (Cordeiro & Echer, 2019; Lobo et al., 2019), but in extreme weather conditions like heavy rains, the crops can withstand brief water logging. In acidified soils, treatment is through liming, this is recommended as it increases the pH to 6.0 or 6.5 which is required to achieve good yield (Alam et al., 2015).

2.4 Agronomic aspects of soya beans value chain

Soya bean production in the developing countries has been improved and this is attributed to the genetic modification of soya bean seed varieties. In Kenya, smallholder farmers practice cultivation of soybeans as stand-alone plants or intercropped with other plants in the farms (Assenga et al., 2016; Hussain, & Nawaz, 2018; Infonet 2019). Large-scale production use fresh, fermented or dried produce to make different products ranging from milk, tofu, soya sauce, bean sprouts among others. Besides its use as feed consumption, they are also used as drugs to cure selected diseases (Rechiatu et al., 2015). For consumption, soya is processed to produce vegetable oil used for salad dressing, cooking among other industrial purposes (As et al., 2017a). In livestock feed, soya beans is highly used to improve the quality and nutrition of livestock feed (Hankinson et al., 2015).

The different types of soybean grown in Africa include; Hill variety, Perry-41, Red Tanner, Sable, Gazelle, Duiker, EAI3600 are grown from 0 -2200mm. Black Hawk and Hill take 120 days to 151 days to physiological maturity. The seeds yield ranges from 1600 kg /ha (Sable) to 2600 kg/ ha (Gazelle and SCS I2). The oil content percentage varies from 16 - 20.7 % for Duiker and Hill respectively, while the protein content varies from 33-35% with an average of 34.4% (Gikonyo et al., 2014a; Mathenge et al., 2019b). The varieties of soybeans grown in Kenya with its different parameters are shown in the Table (2.1) below.

Table 2. 1

Varieties of soybeans grown in Kenya

Characteristics/ varieties	Production altitude(masl)	Days to physiological maturity	Seed yield kg/ha	Oil content (%)	Protein content (%)
Black Hawk	800 -1700	150-165	1.8	18	35
EAI 3600	800-1700	53-142	0.5-2.5	17.8	35
Gazelle	1200-2400	73-175	0.8-2.1	22	35
Hill	1200-2400	140-145	1.8	20.7	33
Nyala	1200-2400	82-163	0.7-2.5	17	33
DPSB 19	900-2400	90-120	0.6-1.7		
DPSB 8	900-2400	120-150	0.5-2.6	18	38
Kensoy009	Cool warm weather	120-150	1.5-3.0		
SC Saga	1000-1800	90-120	2.5-4.5	20-22	37-40
SCS 810/6/26SC (Salama)	1000-1500	90-120	2.0-4.0	20	40

Source: KEPHIS National Plant Variety List (2019)

The viability of soya beans seeds normally in less than ten months but dependent on type and ecological conditions. Hot and damp conditions results to lose of viability. It is recommended that seeds viability be carried out prior to sowing. 100 cultivars are randomly picked from each batch. It is then immersed in a glass of water for a day, then water is drained off and a damp cotton or cloth is inside. The material is kept damp all through. It is expected that in 3-4 days, seed would have germinated and young sprouts seen on all viable seed. Germinated seeds can easily be counted and expressed in percentage. Sprouting as high as 85% is taken good. The required soybean spacing during planting is in rows 40-50 cm apart and within rows sowed ten centimetres apart (Infonet, 2019; Mathenge et al., 2019).

2.5 Nutritional value of soya beans.

Soya bean is highly valued in the world because of it high oil and protein content. It has oil content of 15-22% whereas its protein levels are at 35-40%, vitamins and other minerals (Alam et al., 2015; Pedrozo et al., 2018). Soybeans are not only valued for its dietary contribution, but also for therapeutic purposes. The black coloured beans is said to cure various illnesses and prevent diseases of the heart, liver, kidneys, stomach and bowels (Info net, 2019)

It is also valued due to it multipurpose nature, it is also a key ingredient in the production of over 39 products, from farming to food production to industrial products like adhesives and pharmaceuticals (Neto et al., 2017). Lately it is being used as a source of bio-energy (Asante et al., 2020; Lacerda et al., 2017). The main benefits of soya beans are that unlike other beans, are cholesterol-free, calcium rich, with lots of phosphorous and fibre. It also has the lowest levels of saturated fat making it healthy for consumption (Meena et al., 2018).

2.6 Soya beans production

According to Siamabele (2019), soya beans cultivation area grew rapidly over the last years. It increased from an area of 26.5 million hectares in 1966, 61.1 million hectares in 1996, to a further 121.5 million hectares by 2016 worldwide (FAO, 2017). Reported increase in cultivation area in the USA, Brazil and Argentina was due to the increased pressure of forage in the livestock industry (Neto et al., 2017). The values of soybean globally have outdone other grains that have existed for centuries (Foyer et al., 2019)

According to Khojely et al., (2018), SSA cultivation area also increased from 20,000 hectares and 13,000 tons of yield from 1970s to 1,500,000 hectares and 2,300,000 tons in 2016. However, production has stagnated at 1.1 tons per hectare, which is so low compared to the rest of the world (Lobo et al., 2019). The U.S. Department of Agriculture reported that the world production year 2018/2019 was 360.993 million metric tons. The United States, Brazil and Argentina were estimated to produce 82% of the world's soybeans. The United States produced approximately 123.66 million metric tons (Salem et al., 2019).

In Africa, countries such as South Africa, Nigeria, Zambia, and Uganda are the leading producers. In Kenya, soya beans production is generally very low yet the country boasts of favourable climate to grow soybeans. The production is as low as Kenya 6000-7000 metric tons. According to FAO, 2011& 2013, hectare under soya beans has been greatly deteriorating. Soya beans in Kenya dominate in two main areas, the western region that covers, Kakamega, Vihiga, Busia, Bungoma, Transnzoia, Siaya, Homabay, Migori, Kisii and Nyamira counties. Also grown in the Central and Mount Kenya Highlands region comprising of Kirinyaga, Embu, Meru and Tharaka Nithi Counties (Mathenge et al., 2019b). Small-scale farmers with sizeable lands measuring between 0.1 to 0.2 hectares are the sole producers of this soybean in Kenya. The actual acreage or hectares of in soya bean production in Kisii county specifically is scanty (Neto et al., 2008).

In Kenya, despite soya beans being classified as one of the valuable crops with an untapped potential, for improving the livelihoods and health of households (Meena et al., 2018), production of soya beans has remained low (FAO, 2008). Production has not improved since 1990, yields have since been an average of 800 kg ha^{-1}, and even deteriorates further regionally. As from 1999 to 2003, the annual average production varied between 560 kg-1 in Western region to 100 kg-1 in the Eastern parts of Kenya. The production has been consistent with an average of 2000 metric tons (FAO, 2008). However, the potential of producing higher yields with good quality is possible, and can range from 3000 - 3600 kgha-1, but only with good agronomical practices (Ulzen et al., 2016b).

According to a report by Nicholson et al. (2019), since the year 2000 to 2009 in the western region of Kenya, the projected land area producing soya continued to be less yielding 1500 to 3000 ha/year. From 2009, the production was seen to rise until the year 2012, where yield decreased substantially. This happened despite the accessibility of inputs in retail outlets. Further, production in Kenya is never enough to meet the local demand and other diverse industrial production. Research has shown that farmers in dry areas like Machakos, Kitui, Turkana and Makueni can make over Kshs 170,000 in a span of three months using the SB19 variety (Gikonyo et al., 2014a). However, the shortage is extreme bearing in mind that at least 70,000 metric tons is required annually to meet local demand; however supply rarely meets the demand of 15,000 metric tons per year. The shortage is supplemented with imports from other countries (Mathenge et al., 2019b).

Improved varieties such as SB19 were specifically recommended to farmers in dry regions, where rain is scarce. The cultivars are drought tolerant and only require moisture during planting and flowering. The plant is grown during the short season crop and matures after three months (FarmBiz, 2018). The crops are produced in two seasons within a year unlike maize, which is grown in one season. For every hectare, it is projected that 20 kilograms of seed costing Kenyan shilling 250 a package is used. The yield is sold at Kenyan shilling 150 to 200, so if minimum of 650kilograms of soya is harvested from one hectare, one can reap as much as Kenyan shillings 130,000, supposing a kilogram was sold 200 (FarmBiz, 2018).

Farmers in Kenya face numerous challenges in soya beans production, including biotic, abiotic and socio-economic factors among others. Competition and marketing from cheap imports of soy beans are also factor that limiting domestic production. Additionally, due to the high cost of inputs farmers are not able to access artificial Rhizobium inoculation, and end up using varieties' that have limited ability to fix nitrogen in the soil, BNF is a technology is a game changer only if farmers can afford (Jonas et al., 2020).

Use of poor quality fertilizer results to poor quality seed compared to the quality of imports, this renders local products to lose market (Gikonyo et al., 2014a). Other agronomical practises that cause low yields include; inappropriate crop husbandry methods, low use of fertilizers, poor pest management, inadequate control of weeds, low combination of organic and mineral fertilizers among the smallholder farmers. All this factors lead to reduced yields of soy beans in areas where low soil fertility is already a problem (Jonas et al., 2020).

2.7 The role of nitrogen on growth and seed yield of soya beans

The demand for high level of nitrogen by soybean seeds is due to the high protein content. Normally, soya beans develop root nodules aided by rhizobia bacterium, which fixes atmospheric N2 that is used up by the crop. The absorbed nitrogen acquired by BNF or from nitrogen absorption is proportionate to the output. This makes N, a key element, and sustainability of required and prolonged BNF process is vital to improved yield production (Ohyama et al., 2017)

The demand for N is estimated to be around 80 kg for production produce 1,000 kg of grains (Asei et al., 2015). According to (Zhou et al., 2019)application of N affects the carbon breakdown and biomass build-up completely. Application of nitrogen at flowering phase influences crop development and production significantly (Pedrozo, Oliveira, et al., 2018). Science shows use of nitrogen in the first stage of reproduction greatly improves yield (Alam et al., 2015). However, the effect of nitrogen on biomass and carbon breakdown was unclear (Hankinson et al., 2015).Application of Phosphorus on soya beans is reported to augment the N obtained from the atmosphere by the soya beans, it is known as brady rhizobium symbiotic system (Chienu et al., 2008; Sanginga et al., 2003). Key mechanism in soy beans cultivation include nitrogen fixation and mineral nitrogen assimilation, this is highly recommended as they steer a high vegetative growth productivity thereby influencing seed protein content (Solomon et al., 2012).

Soil-N plays a critical role in producing N because 25% to 65% of nitrogen in soya beans dry matter is from synergetic nitrogen conversion (Sylvain, 2020). Additionally, (Neto et al., 2017), authored that soya beans plants act as link for soil-N and effectively uses N irrespective of where it came from. Moreover, Alam et al., 2015, that N fertilization of soya beans positively impacts seed protein and oil concentration. The primary function of N application as a starter is to supply soya beans with readily available soil-N during seedling development, evidently N increases soya beans grain yield (Asei et al., 2015)

Even though the cost involved in the use of inoculants is high, it is still a good alternative in achieving maximum yield (Filho et al., 2017). Inoculants such as rhizobium fix nitrogen from the air nitrogen within the roots and makes N accessible to the host. Additionally, BNF of crops is strictly depended on for development and leghaemoglobin content in the root nodules, crops meet their required nitrogen amount in that way (Pedrozo et al., 2018).

The BNF occurs through sequential processes that starts with bacteria adaptation to the plant and leads to environmental nitrogen conversion (Santos et al., 2019; Hungria & Mendes, 2015). Nodulation thereafter follows within two hours of interaction between the bacterium and roots (Santos et al., 2019). According to Alam et al., (2015), enzymatic nitrogenase processes begins declining when beans formation starts developing, as a result of photosynthetic products competition in the nodules, pods and beans. Such competition limits nitrogen needed for filling of seeds in the pods, hence low yield (Hankinson et al., 2015; Neto et al., 2017). According to Araujo et al. (2017) reduced nitrogen levels takes place in the leafs when the pods are development. This is because nitrogen is moved to generate pods and seeds. Therefore, during the reproductive phase, nitrogen mobilized meet the demand for seeds and pods development, results to reduction in BNF, ultimately affecting the overall growth of the beans (Sylvain, 2020).

To note is that direct contact of nitrate with already formed nodules normally results to restriction in nodule growth and BNF, although, the distal areas of nodules do not suffer any consequence. Application of slow-release nitrogen manures deep into the soil, coated urea or lime nitrogen is also recommended to promote the growth and quality of beans without affecting BNF (Ohyama et al., 2017).

Available inoculants in the market that have been tested and proven to increase yield include molybdenum, cobalt and rhizobium among others. The inoculants can be manufactured either singly or in mixed combination. According to (Santos et al., 2019), prior inoculants comprised only one species of microorganism, except in cases where there was combination of two strains of the same type two microorganisms e.g. two *Bradyrhizobium* strains. Inoculation is effective in the enhancement of rhizobia, which subsequently aids in crop growth and soil fertility. Use of inoculants in soybean production especially in areas that have poor productivity and low soil fertility like Kisii is recommended because this practise is done in many places across the world (Ulzen et al., 2016b).

2.8 Effect of di-ammonium phosphate fertilizer, molybdenum, cobalt and rhizobium inoculants on the growth and yield of soya beans.

The main objective of using inoculants is to improve productivity and yield of crops cultivated. Many research studies have reported use of rhizobium inoculant as a viable alternative to enhancing better growth and improving yield of soya beans globally. It is reported that, the total number of nodules increases with inoculant coated seeds as opposed to non-inoculated (Ulzen et al., 2016b). Soya beans nodulation ,growth and yield is also noted to be significantly influenced by mycorrhizal inoculation (Ibrahim , 2015). Mycorrhiza is widespread symbiotic associations that results from evolutionary processes between the plants roots and fungi, the influence causes ecosystem transformation in plants thereby improving plant performance precipitated by increased micronutrient assimilation (Meena et al., 2018).

In a study done by (Ibrahim, 2015), the results showed that, the outcome of rhizobia, DAP and mycorrhizal synergy considerably multiplied nodule per plant resulting to comparative accelerated growth and yield of soya beans unlike the control treatment. In Khartoum, watered soya beans yielded considerably better in an experiment that combined rhizobia inoculant, DAP and mycorrhiza in cold weather (Meena et al., 2018). Similarly, in another study, dual inoculation with mycorrhiza and *Bradyrhizobium* showed a substantial multiplication in nodules number in soybean in comparison to the control (Pedrozo, et al., 2018).

2.8.1 Effect of diammonium phosphate fertilizer on the growth and yield of soya.

Globally, DAP is a popular phosphorus fertilizer utilised in farming, it comprises of, nitrogen (18%) and 46% of Phosphorus oxide (Dagash, 2015). The high amount of protein content in soya beans makes it a high nitrogen demanding crop. BNF and mineral soil and use of fertilizer rich in nitrogen are ways in which nitrogen requirement of high yielding soybean is met (Cordeiro & Echer, 2019). Lack of phosphorus (P) could decrease nodulation and growth performance, subsequently resulting to poor yield, therefore, application of P is known to mitigate the deficiency (Rechiatu et al., 2015). According to Staton (2014), the key to leveraging on phosphorus and potassium applications in economic gains is by undertaking in-depth soil analysis. For significant crop performance, P and K in soil should always be maintained above permissible limits. In soils, the allowed limit for a particular micro nutrient is described as soil levels at which 95 to 97 percent yield potential is attained without adding any other micronutrient (Cordeiro & Echer, 2019). The permissible limits for phosphorus is 15 parts per million (ppm) , while the required limit range for soybeans sustainability is also 15 ppm, therefore P in soil should be upheld at arrange of 15 to 30 ppm. The yield from soya beans is estimated at 0.8 pounds per bushel of phosphorus oxide. So for 60-bushel per acre of soybean yield, 48 pounds in every acre of pure phosphorus oxide or 90 pounds in every acre of mono ammonium phosphate (MAP) or 100 pounds in an acre of DAP is needed. In the USA, use of P during spring fertilizers is preferred to fall where the soil pH levels rise to 7.4. This preference boosts P availability by decreasing the amount tied up in the soil (Ibrahim , 2015).

Importance of soya beans is well documented and emphasized in literature. It contributes well approximately 60% vegetable protein and 30% oil to the world consumption. Besides protein and oil, soybeans also contain various vitamins and minerals. Many trials on soybean have been conducted globally, in Sudan for example, experiments were initiated as early as in the early 1920 and where very scanty yields were reported to have been obtained (Ibrahim , 2015; Yagoub et al., 2012). This was associated to shortage in varieties that could opt to Sudan's weather conditions.

On the other hand Darwesh et al., 2013, confirmed that treatment with phosphate increased production in an experiment conducted on soya beans. Similarly, Cordeiro and Echer, (2019) reported that results from plots that had three graded levels P (10, 20, 30) kilograms of phosphorus per hectare showed increased weight of seeds. Averagely, P response ranged from 87 kilograms per hectare (P10) to 217 kilograms per hectare (P30). The output depicted that increased levels of P resulted to better performance of plants (Cordeiro & Echer, 2019). Further, use of 120 kilograms per hectare was shown have high yield (1955.56) as oppose to the control that yielded (1274.07 Kg/ha-1).

Additionally, analysis of growth parameters i.e. height was seen to be positively influenced. The reported longest height was (56.2 cm) in P of 120 kilograms per hectare the shortest height in the control was (49.37 cm). To note is that use of unimproved seed type and inputs, reported yields decreased even in alkaline soil conditions. This is because P is converted instantly to calcareous resulting to poor absorption in the roots. It is vital to state that soy beans respond towards P variably in alkaline soils, as it is dependent on soil pH, fertility and the genotype (Dagash, 2015).

According to Filho et al.(2017) and Meena et al.(2018), the experiment conducted to evaluate the growth performance using varieties of cultivars exposed to different levels of P yielded poorly, this was due to scarcity and unbalanced micro nutrition in propagated soya bean. Fixation of P in Alkaline soil require more nutrients to meet conversion and plant needs (As et al., 2017a). It is reported that alkaline soils are have poor fertility and normally needs higher nutrient level s to guarantee good yield. Even so, P is regarded as a significant micronutrient, after nitrogen in crop production (Meena et al., 2018).

Notably, Lambon (2016) pointed out that application of DAP manifest itself differently depending on plant height and soy bean type. Further, it was noted that during the early part of plant growth, the energy requirements is minimal. However, with increase in plant body, more resources are used, and therefore growth becomes rapid. Plant height increased greatly (about 300 %) between 20 and 40 DAP but slows as the plant gets into reproductive stage.

Combination of DAP and rhizobium in study done in northern Ghana showed positive results as it influenced the growth parameters including; height, leave surface area, nodules count, bud weight and yield. Using p at different rate in combination with rhizobium inoculant, the study results showed significant increase in all parameters. Based on the findings, rhizobium inoculants combined with triple superphosphate fertilizer at 30 kilograms per hectare was recommended as a good inoculant prior to cultivation of soya beans cultivars (Sylvain, 2020).

Additionally, Lobo et al., (2019), notes that P is essential in energy metabolism especially in BNF, a process that requires energy process. For good nodulation, P is required in high amounts (Hc & Aa, 2019). Multiplication of nodules and nitrogenase activity is reported to increase with the increase of P meaning, maximum BNF (Alam, , et al., 2015). In addition to the benefits of P on nodulation process and plantgrowth, phosphorus, is reported to also influence soil rhizobia directly (Meena et al., 2018).

Study results from an experiment carried out by Hankinson et al., 2015, revealed that use of P substantially enhanced the growth and yield of soya. Similarly, in another study, it was observed that rhizobium and 100 mycorrhiza (RM) and 150 kilograms per hectare of DAP produced more nodules in per plant compared to the control. The study assumed that, due to the increased co evolutionary process resulting from symbiotic relationship, multiplication of nodules increased (As et al., 2017a).

2.8.2 Effect of molybdenum on the growth and yield of soya beans.

Molybdenum (Mo) is essential for nitrogen metabolism and protein synthesis in plants. In BNF, Mo acts as a cofactor for nitrogenase enzymes to accelerate the oxygen reduction (redox) reaction in conversion of nitrogen into ammonium (NH4 +) ions (Alam et al., 2015). Further, Filho et al., 2017, adds that Mo is a part of the nitrate reductase enzyme ,a structural component involved in BNF, which has symbiotic relationship with leguminous plants. Micronutrient which are essential in growth of plants are applied in minimal amounts compared to other nutrients (Pedrozo et al., 2018). One of the studies on soya beans revealed that molybdenum important in BNF and enzyme activation addition of other micronutrients such as iron, and cobalt affected growth and yield significantly (Rechiatu et al., 2015).

Reports from Neto et al., (2017) depicted brady rhizobium inoculants to multiply nodules in soya beans. Increased nitrogenase activity was due to seed inoculation with Mo application in soya bean. Further, it was observed that N uptake in soya beans increased with Mo application (Asei et al., 2015). Mo application significantly increases the leaves, stem, nodules and the total dry weight of soya beans. All parameters from the plants that were weighed after drying positively correlated with Mo concentrate ion. It was noted that soya beans yield increased by 46% due to the use of one kilogram of Mo per hectare (Alam, et al., 2015; Crusciol et al., 2019; Filho et al., 2017).

Deficiency of Mo is common in weathered acidic soils and hinders the capacity of plants to carry out BNF. However, Mo is needed in small amounts, actually, normal plant tissues have 0.8 to 5.0 parts per million (ppm), in plants with low levels below 0.5ppm. others such as corn and grass could only have 0.1 ppm of Mo (Asei et al., 2015; Rechiatu et al., 2015).

Report from studies done by Asei et al., 2015 from an experiment that tested legumefix and teprosyn Mo treatments noted an increase in yield. It also revealed that use of Mo was found to be the most economically viable treatment (VCR = 2.65) (Alam, Kim, et al., 2015). Further, the output showed that dry weight of nodules increased in Mo application. Similarly, Asei et al., (2015) study affirms that use of Legume fix produced more than 50% improvement in their research. Moreover, the yield was enhanced when combined with Teprosyn Mo by 205.62%. additionally, combination of Teprosyn Mo and Legume fix showed more economic gains (VCR = 2.65) (Filho et al., 2017)

Inoculation with cobalt and Molybdenum of seeds prior to sowing showed increased micronutrient in leaves and mass of 100 grains. Additionally, molybdenum treatment is reported to decreases iron content in leaves, but not on soybean yield. It was also noted that, molybdenum was mostly in small amounts in plants compared to other micronutrient and it is also least required in plants. Symptomatic deficiency of Mo in plants is depicted just like in nitrogen deficiency discussed earlier in this chapter (Filho et al., 2017).

Use of Mo is also limited by the soil PH, acidified soils decreases Mo availability due to increase in iron and aluminium solubility. Additionally, sandy soils contained low levels of Mo (Alam et al., 2015).To counter acidified effects, liming acid soils is recommended to maintain the permissible levels (Asei et al., 2015). Seed treatments is noted to increase fertilizer intake efficiency, giving better use of resources, Mo application by seed treatment has proved to be effective and economical in increasing seed yields (Alam et al., 2015; Asei et al., 2015; Filho et al., 2017).

2.8.3 Effect of cobalt (Co) inoculants on the growth and yield of soya beans

Cobalt (Co) is a micronutrient available in minimal amounts in soil. Cobalt is a factor of cobalamine enzyme responsible in development of the nodules. It is also significant in BNF as it enhances leghaemoglobin establishment needed, with resultant improved nodulation (Cordeiro & Echer, 2019; Zhou et al., 2019). According to Filho et al. (2017), cautious use of Co is important as excess of it leads to toxicity in plants and subsequent reduction in iron and magnesium absorption, causing deficit of these micronutrients in plants. According to (Siamabele, 2019), use of *A. brasilense* with cobalt and molybdenum was exhibit highly in leaf and mass of at least 100 grains. According to Meena et al. (2018), such effects leads to better nutrition and yields.

Further, Ulzen et al. (2016a) attributed the large number of nodules observed on soya beans to Mo and CO. As Mo accelerates redox , Co on the other side aids in BNF fixing micro-organisms. Observations by Oliveira, et al., 2018, revealed that use of cobalt at

1.2mg kg^{-1} boosted performance of soya bean. Interestingly, Araujo et al., 2017 also noted that leaf surface area, and other yield parameters of soybean were positively influenced by cobalt and molybdenum.Finally, Filho et al., (2017) noted that excess application of cobalt at doses higher than 3.4 g ha−1 was poisonous to soybean. Similarly, Lacerda et al., (2017) noted a decrease in height, leaf zinc concentration, and yield with added amount of cobalt.

2.8.4 Effect of rhizobium on the growth and yield of soya beans.

Rhizobacteria (PGPR) and phosphate-solubilizing bacteria (PSB) are beneficial microorganisms in BNF (Lamptey et al., 2014a). According to Lobo et al., (2019) bacteria that live in rhizospheric microenvironment can produce favorable , neutral, variable, or deleterious effects on plant performance (Barea, 2015). Bacteria access plant root through the root hairs, which forms nodules (Hungria & Mendes, 2015). Use of *Bradyrhizobium* is now a routine practice in cultivation of soybean in the Brazilian farms (Takahashi, 2020). Its efficiency and effectiveness causes improved yields. Biological nitrogen fixation influenced by *bradyrhizobium* genus is cost effective and facilitated sustainable soybean farming (Pedrozo,et al., 2018)

Consequently, use of rhizobia has led to higher competition of soya globally. All this is a result of increased production and replacement of nitrogen only fertilization (Filho et al., 2017; Gikonyo et al., 2014a; Sylvain, 2020)

Inability of soil response to rhizobia is said to occur where there is availability of adequate amount number of indigenous rhizobia, this therefore competes with new strain applied for nodule occupancy (Alam et al., 2015; Kubota et al., 2008; Ulzen et al., 2016a). To confirm this, (Asei et al., 2015), reported no substantial differences in nodule dry weight among the treatments fin an experiment that introduced rhizobia during sowing. The indigenous rhizobia population was 4.36 × 101 while the adopted rhizobia population was 1 x 102 rhizobia cell g-1. It was observed that nodulation was prevented and naturalized rhizobium was dislodged

This confirms that during propagation, nodulation process, is dependent on both abiotic and biotic factors, with also live bacteria population (Sayyed et al., 2019). Death of the naturalized bacteria from any cause negatively affects the formation of nodules and, in turn, BNF. Several factors including; dryness, temperature, and seed coat toxicity,, are linked to poor survival of bacteria inoculated in seeds (Mathenge et al., 2019b). Fungicides been shown toxity to bacteria and leads to death immediately after inoculation (Sayyed et al., 2019). Pre-inoculation conditions, can also affect the bacteria negatively (Lobo et al., 2019), innovative technologies should be developed to promote the survival of the bacteria on the seeds for long duration considering the harmful chemicals (Araujo et al., 2017).

As noted by Pedrozo, et al., (2018), application of *Bradyrhizobium* during planting enhance multiplication and dry eight of nodules compared to treatments without inoculation (Rechiatu et al., 2015). Additionally, plants height increased when Ca+B was added (Sylvain, 2020). Nitrogen content was seen to increase when *bradyrhizobium* inoculation at sowing in one of the experiments (Araujo et al., 2017).

As explained by (Etopobong, 2017)), the author pointed out that the growth and yield parameters of the soybean improved on treatment with organic fertilizer coupled with

Rhizobium inoculation. The growth and grain yield enhancements observed in this investigation might have been attributed to an increased symbiotic relationship of rhizobia (bacteria) with the roots of leguminous crops resulting to a possible fixation of atmospheric nitrogen into the roots of soybean which was favored by P nutrition (Sylvain, 2020).

Poorly drained, waterlogged lands are detrimental plant root growth and to *Rhizobia.* Emphasis is placed on proper monitoring and maintenance of soil PH to realize for optimum legume production (Tahir et al., 2009; Ulzen et al., 2016b). Therefore, because *Rhizobia* is dependent on the host for the energy which is required in BNF, any factor that hinders normal growth and development will ultimately influence BNF (Pedrozo, , et al., 2018).

A study report by Hc and Aa (2019), soybean inoculated with Nodumax (irrespective of adhesive agents) was noted to increase the root length, nodule numbers, root dry weight and number of roots than untreated control. The increased activity of *rhizobium* and other indigenous soil microorganism enhances nitrogen fixation and promotes root growth, thereby increasing the yield of legume plants (Asante et al., 2020). Gum Arabic is known to maintain the survival of *rhizobium* in the face of inadequate nutrients in acidic soil of cultivated area. It can produce more than 50 nodules per plant at anthesis. It is reported that use of sticking agent with correct type and adequate amount of inoculants greatly increased the number of rhizobia adhering to the seed. Inoculated soybeans in many research studies has demonstrated significantly higher number of nodules and roots with subsequent increase in root weights and yield (Hc & Aa, 2019).

2.8.5 Effect of combinations of cobalt, molybdenum and rhizobium inoculants on the growth and yield of soya beans.

Considering the current limitations in soybean production, the potential of biological fixation of N2 (BNF) using combined inoculants is now a viable option. Use of two species of bacteria, *Bradyrhizobium* sp. and *A. brasilense* for instance, has been reported to improve the crop performance. Such results are viable to meeting the current demands of agricultural, economic, and environmental sustainability (Ulzen et al., 2016a).

Use of a mixture of inoculants in soya beans cultivation has been shown to aid the root system that assists increased assimilation of water and micronutrients with resultant improved nutrition and yields (Darwesh et al., 2013; Hankinson et al., 2015; Ferri et al., 2017; Pedrozo, et al., 2018; Ulzen et al., 2016a).

Increase in yield is attributed to several mechanisms influencing the process of BNF in the nodes, which eventually increases dry weight of nodules. BNF promotes the rate heterogous nodulation by accelerating the development of the root system. Further, factors such as; increase in infection sites, inhibition of plant pathogens and production of phyto hormones influences the partition of dry matter between the roots and shoots (Meena et al., 2018) . Use of *A. brasilense* with *Brady rhizobium*spp in common bean showed impressive increases in grain yield since inception of the inoculants in 2014 (Araujo et al., 2017; Campo et al., 2010).

Several reports have also pointed out that use of two inoculants in sowing is efficient as it increases yield even in limiting conditions, such low phosphate soils. (As et al., 2017). Lamptey et al., (2014) established that soya beans planted with rhizobium (Legumefix) developed better, has they had more leafs, more shoot biomass during pod formation phase, increased nodulation at maximum pod stage with subsequent many pods. This is evident that use of inoculants in set ups with reported low yield is vital (Asei et al., 2015).

Further, growth parameter shave also been shown to increase with co inoculation (Lambon 2016).Moreover, Meena et al., (2018) also noted nitrogen and phosphorus as important nutrients in growth and productivity of plants. Additionally, it was demonstrated that the synergistic interaction(s) of bacteria and mycorrhiza stimulated growth and development of beans via increased N and P uptake (Ulzen et al., 2016b). From other experiments, the interaction between rhizobium and mycorrhiza (RM) was shown to increase grain yield significantly compared to control (Dagash, 2015). Similarly, Argaw (2016) demonstrated boosted growth and yield with combined inoculants with rhizobium and mycorrhiza increased yields of soybean.

CHAPTER THREE

RESEARCH METHODOLOGY

3.0. Introduction.

This section describes the study setting, and the research design used the type of treatment, land preparation and planting procedures. Additionally, the experimental layout is illustrated, data collection techniques, parameter collected and data analysis technique is explained.

3.1. Study Site Description

Location

The experiment was conducted at Kisii Agricultural Training Centre farm within high soya beans producing areas in Kisii County. It was conducted during the short rain season.

Climatology

The agro ecological zones, lies between 1000m- 1500m above sea, and is humid with an estimated temperature of 21-30 ^{0}C, the yearly rains averages 1500mm. The area has an upland equatorial climate due to the bimodal rainfall pattern experienced in the region. The long rains are experienced between February and June, while the short rains occur between September and early December. The highest temperatures recorded in the county ranges 21°C – 30°C while the least is 15°C – 20°C. Adequate rainfalls, together with the favourable temperature in Kisii are appropriate for crops such as tea, coffee, pyrethrum etc. (Kisii County Agriculture, 2013).

Soils

The study area is characterized by a hilly topography with red volcanic soils- nitosols (75%), rich in organic matter. The region also has a mixture of clay soils, red loams and sandy soils. The soils have low soil fertility due to low mineral content and low caution exchange capacity (Jaetzold et al., 2006).

3.2 Experimental research design

The trial adopted a Randomised Complete Block Design (RCBD) in four replications (Fig 3.1). RCBD was used to secure against experimental plot terrain slope of 5%.

3.3 Treatments and treatment combinations

The treatments used consisted of; Rhizoliq Top Soya 3m/kg, Wuxal Extra CoMo15 1ml at /kg of seed, Wuxal Extra CoMo 15 at 1.5 mls/kg of seed, (Wuxal Extra CoMo 15 at 1mls/kg/ Rhilizoliq top 3mls), (Waxul Extra15 CoMo1.5m/Rhizoliq top 3ml/kg)and Control (Without Treatment), DAP, of soya seed. Soybean SC SAGA variety was used, DAP fertilizer applied to all treatments at 125 kg $ha^{-1.}$ The experiment was done during the short rain season of September-December 2018. Other agronomic practices were carried out as required.

3.4 Experimental layout

The experimental plots were 28, each measuring 3 x 2 m. Access footpaths of 2m spacing separated adjacent 4 blocks

Table 3.2

Experimental layout in Randomized Complete Block Design (RCBD)

Block1

WT	DAP	CoMo 1ml	CoMo1.5 ml
	CoMo1m/Rhzq	Rhzq	CoMo1.5 ml/Rhzq

Block2

DAP	CoMo1 m	CoMo 1.5ml	
Rhzq/CoMo1.5ml	Rhzq	Rhzq/CoMo 1ml	WT

PATH

WT	DAP	CoMo 1 ml	Rhzq/CoMoI ml
	CoMo1.5 ml	Rhzq	Rhzq/CoMoI.5ml
Block 3			

CoMo1ml	Rhzq/CoMoI.5 ml	Rhzq/CoMo1m	WT
CoMoI.5 ml	DAP	Rhzq	
Block 4			

Key: WT (without treatment) **2**.CoMo (Cobalt/Molybdenum) **3**.Rhzq-Rhizoliq(Rhizobium) **4**.DAP (Diamonium phosphate)

3.5 Land preparation and planting

Land was ploughed and, harrowed to give a moderate tilth the beans were then sowed with a spacing of 45 cm by 10 cm at the beginning of the rainy season giving a total population of 444,444 plants/ha. The seeds were inoculated prior to sowing with the, seed rate of 20 kg/acre SC SAGA variety. A sample of treated seed was also taken for physical assessment of damage during the treatment.

Soybeans seeds viability is within six to ten months but dependent on type of cultivar and ecological conditions, more so in hot and damp conditions. Prior to planting, viability was tested. Treatments had the same plant density in order to avoid distortions in the assessments done throughout the crop cycle.

All blocks were planted at a rate of two seeds per hill, 21 days after germination, thinning was done to achieve one seedling. During planting seed, samples were also subjected to untreated check (UTC) to analyze its germination percentage. Planting was first done to the UTC seeds and then the rest of the treatments, to avoid cross-contamination. Hand weeding commenced with the control plot to avoid contamination with rhizobium bacteria.

Due to the use of biological products, all conditions from storage to planting were maintained (mild temperatures, away from direct sunlight, etc.). Sudden temperature changes were avoided, so as not to effect bacteria survival. Seed treatments were applied in the shadow and away from sunlight.

3.6 Data collection procedures

Soil samples were collected prior to the experiment from uniformly distributed point with an auger at the experimental site using the grid sampling method. Four sub-samples (0-15 cm depth) were randomly picked from individual plots, air-dried and ground, then pass through a 2-mm sieve. It was then mixed to form composite samples for each plot.

Other data collected included land use for the previous seasons, rainfall records using rain gauge at CRF and Metrological department at Kenya Agricultural and Livestock

Research Centre Kisii. All the trial events were geo-referenced. Pictures were taken during planting and at every visit to the trial site

All through the experiment six plants (6) were randomly selected per plot; the plants selected were away from the edge of the plot i.e. from the third plant inside the plot. Data collected included; germination percentage, flowering percentage, above ground biomass, six plant pod weight, 100 seed weight, number of branches at harvest., number of pods at harvest, plant height at harvest and grain yield.

3.7 Data management and analysis

The physical and chemical properties were analyzed using the standard methods as outlined by (Jackson, 1973; Okalebo, et al., 2002; Nelson & Sommers, 1975; Lindsay & Norvell, 1978). Test done on the samples collected included: Organic carbon, total nitrogen, extractable phosphorus, extractable potassium, pH (water), electrical conductivity and particle size distribution. Additionally, the soil type pH (1:2 soil/water), organic carbon (%) Textural class, N (kg ha), P (kg ha-1), K (kg ha-1), S, Zn, Mg, Cu, Fe, Mn, Co and Mo was also carried out. The pH was measured using standard pH meter in a 1:2 soil/water suspension. The tests were done at KALRO Kisii lab before and after planting on basic soil nutrients (NPK) and levels of cobalt and molybdenum in soil at CROP NUTS soil analysis lab, Nairobi. The soil was tested using dried chemistry process at Crop Nuts/KARLO Laboratories.

The collected data on growth and yield parameters was analysed using SPSS Version 24.0 statistical package. ANOVA was to manipulate data (α 0.05), thereafter results that showed statistically significant difference were further subjected to Duncan multiple range (DMRT) -post hoc test to separate means. Results was then visualised using tables and charts.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.0 Introduction.

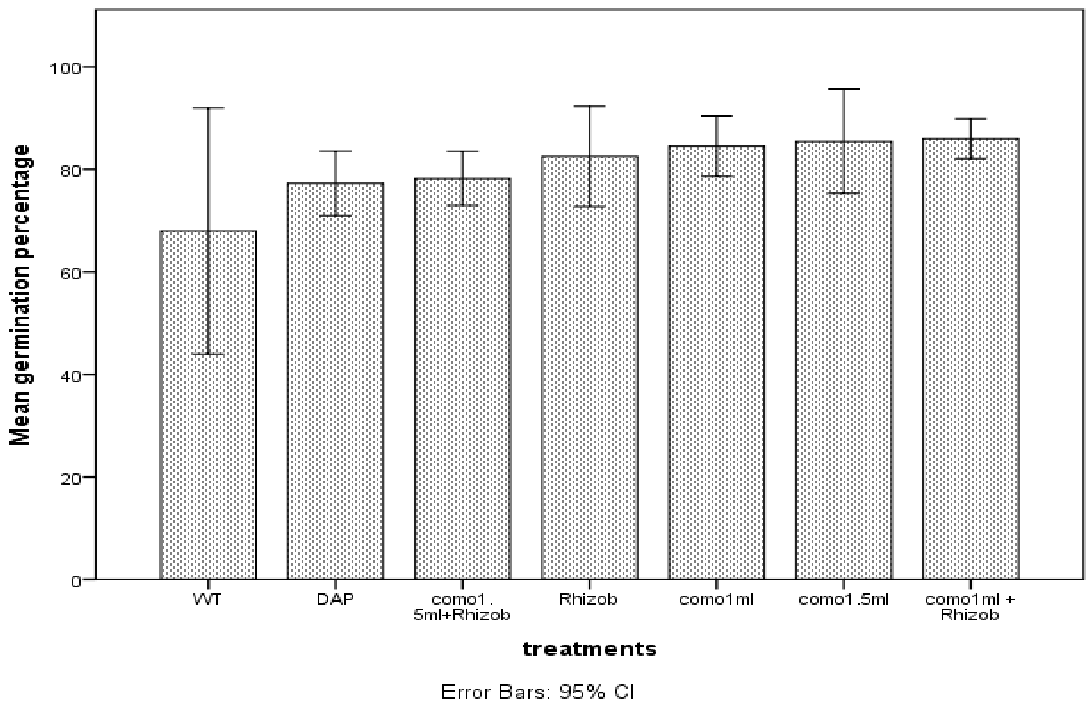
Several parameters on growth and yield of soya beans were analyzed and the results were presented and discussed in details in the following section. Soils analysis showed moderate electrical conductivity (0.06 µs/cm), adequate levels of organic carbon (2.4%), manganese (1.5%) and phosphorus ppm (20). However, the nitrogen and potassium level was found to be low (0.12) and (40%) respectively. The soil was found to be moderately acidic (5.5) with Co and Mo levels at 54.6 Mg/lg and 6.44 Mg/lg respectively. It is important to note that that the type of inoculant and the soil PH significantly affects the seed growth and yield. Therefore, test of soil PH is a very critical factor before deciding on the best inoculants. The results by Asei et al. (2015) showed that, molybdenum availability decreased as anion adsorption to soil oxides increased. Salinity and acidified soils are reported to cause damage to rhizobia.

4.1 Effects of different levels of cobalt/molybdenum, rhizobium inoculants and diammonium phosphate fertilizer on germination percentage.

Germination percentage is a growth parameter that measures various treatment efficacies. On the 14^{th} day, the sprouts in all the plots within the blocks were counted. The average plants germination percentage was calculated by taking the number of germinated plants against total number of planted population times 100. The mean germination percentage of the treatments is depicted in figure 4.1. Results showed WT (control) plots exhibited the lowest percentage compared to all the treatments, while CoMo1ml+Rhizob had the highest germination percentage, followed by CoMo1.5ml.

Figure 4.1

Mean germination percentage.



ANOVA showed a statistically significant difference between treatments, P (<0.019).

Table 4. 3

ANOVA on the effect of inoculants on germination percentage

Dependent Variable: Germination percentage

Source	**Type III Sum of Squares**	**Df**	**Mean Square**	**F**	**Sig.**
Block	199.429	3	66.476	1.396	.276
Treatments	987.214	6	164.536	3.456	.019
Error	857.071	18	47.615		
Total	2043.714	27			

Post hoc test was thereafter performed using DMRT and the results were as depicted in table 4.4 below.

Table 4.4

DMRT for germination percentage

Treatments	Subset
Control(WT)	68.00a
DAP	77.25ab
CoMo1.5+Rhizob	78.25ab
Rhizob	82.50c
CoMo1	84.50c
CoMo1.5	85.50c
CoMo1+Rhizob	86.00c

Means difference significant at 0.05 levels

The control (a) was significantly different to all other treatments being the least but in same category with DAP and CoMo1.5ml+Rhizob (ab) but statistically different from Rhizob, CoMo1, CoMo1.5 and CoMo1m+Rhizobia (c) in same category, but CoMo1m/Rhizobia have the highest percentage germination.

For effective rhizobia and legume interaction, compatibility is necessary for the adequate development of nitrogen conversion nodules (Htwe et al., 2018). The beneficial effects of plant growth promoting rhizobacteria (PGPR) and rhizobia in common bean was shown to possess synergistic influence growth (Korir et al., 2017). Influence on soya beans growth was exhibited in an experiment undertaken by Silva et al., (2019) using Bradyrhizobium Japonicum together with Azospirillum brasilense. Similarly, another study done in Nyankpala showed significantly more fresh and dry sprouts of 74.2 g and

23.57 g per crop respectively as compared to those that were not inoculated (Ulzen et al., 2016c).

Literature evaluating effect of co inoculation on the germination of soya beans cultivars is scanty. Many authors have dwelt on other growth parameters that demonstrate effectiveness of inoculants under study. Nevertheless, it is important to conclude that, influence of co inoculation with CoMo significantly increases the germination rate of soya beans. Use of inoculants in soya beans cultivation is a success ticket for small scale farmer in Kenya.

4.2 Effects of different levels of cobalt/molybdenum, rhizobium inoculants and diammonium phosphate fertilizer on flowering percentage

The flower count was undertaken when the fields had reached 50 % flowering and was done at 60 days after sowing. The flowering effect was averagely measured against each treatment per plot and data recorded. CoMo1ml +Rhizobium had the highest flowering percentage while DAP (WT) control had the lowest flowering percentage

Table 4. 5

ANOVA on the effect of inoculants on flowering percentage

Dependent Variable: flowering percentage 50%

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.
Block	3242.000	3	1080.667	23.185	.000
Treat	715.000	6	119.167	2.557	.057
Error	839.000	18	46.611		
Total	4796.000	27			

ANOVA indicated no significant difference between treatments value (0.057>0.05)

Flowering is a measure of the extent of plant growth. Flowering indicates reproductive phase in soya beans. Each stage (R1-R8) of reproduction during flowing to maturity depicts continuous pod developments stages. Some factors such as plant development period, soil fertility etc. are known to influence flowering of legumes (Purcell et al., 2014). In a study done by Oliveira, et al., 2018, soya beans exhibited quick flowering in 50% of the plants that were picked. Similarly, Zhou et al., (2019) found that application of inoculant at flowering stage influenced the reproductive growth and grain yield significantly. In addition, plants that were harvested during flowering following pre-treatment with rhizobium exhibited considerably increased fresh and dry shoot matter, that was in comparison with plants that had not been inoculated (Lamptey et al., 2014b).

4.3 Effects of different levels of cobalt/molybdenum, rhizobium inoculants and diammonium phosphate fertilizer on above ground biomass

The above ground plant biomass in kilograms per plot was measured during harvesting period with removal of plants at 95% functional maturity. The average heaviness of above ground shoots for various treatments. The results showed CoMo1.5ml / Rhizob, followed by CoMo ml + Rhizobia treatment, exhibited the highest above ground biomass weight and the least was WT. ANOVA test was conducted to determine the mean differences among biomass weight of treatments the results are indicated in the table 4.6. The weight of biomass of different treatments indicated there no significant difference among treatments P value (0.085>0.05) no further test was subjected.

Table 4.6

ANOVA on the effect of inoculants on above ground biomass.

Dependent Variable: weight of biomass whole plot in kg

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.
Block	1.018	1	1.018	.758	.394
Treat	17.772	6	2.962	2.208	.085
Error	26.835	20	1.342		
Corrected Total	45.624	27			

According to the finding by Ulzen et al., (2016c), above ground biomass was significantly influenced ($P \leq 0.01$) by rhizobium. These results concurred with that of Hungria and Mendes (2015) who stated that there was a considerable improvement in nodulation and biomass when rhizobium was used. On the other hand, Hankinson et al., (2015) contrasted the observation by reporting that, inoculants has a very small effect on soya been biomass and quality of yield. Another study that evaluated Rhizob ium effect on shoot Biomass, found higher fresh and dry shoot weight (74.2 g and 23.57 g per plant) compared to the non-inoculated (Lamptey et al., 2014b). Additionally, finding published by Alam et al., (2015), confirmed that molybdenum increased biomass weight, the study suggested that the higher the enzymatic activity, the higher the nitrogen assimilation hence the effect on growth of soybeans. Studies have recommended use of inoculants to promote for better plant biomass and subsequent improved yield.

4.4 Effects of different levels of cobalt/molybdenum, rhizobium inoculants and diammonium phosphate fertilizer on six plants pod weight

Six plants were randomly selected per plot per treatment and pods harvested at physiological maturity. The pods were weighed in grams using an electronic weighing balance. The treatment of CoMo1ml+ Rhizobium had the highest pod weight per plant. The control and CoMo1ml treatments had the lowest pod weights per plant (Figure 4.2)

Figure 4.2

The mean weight of pods in grams per plant

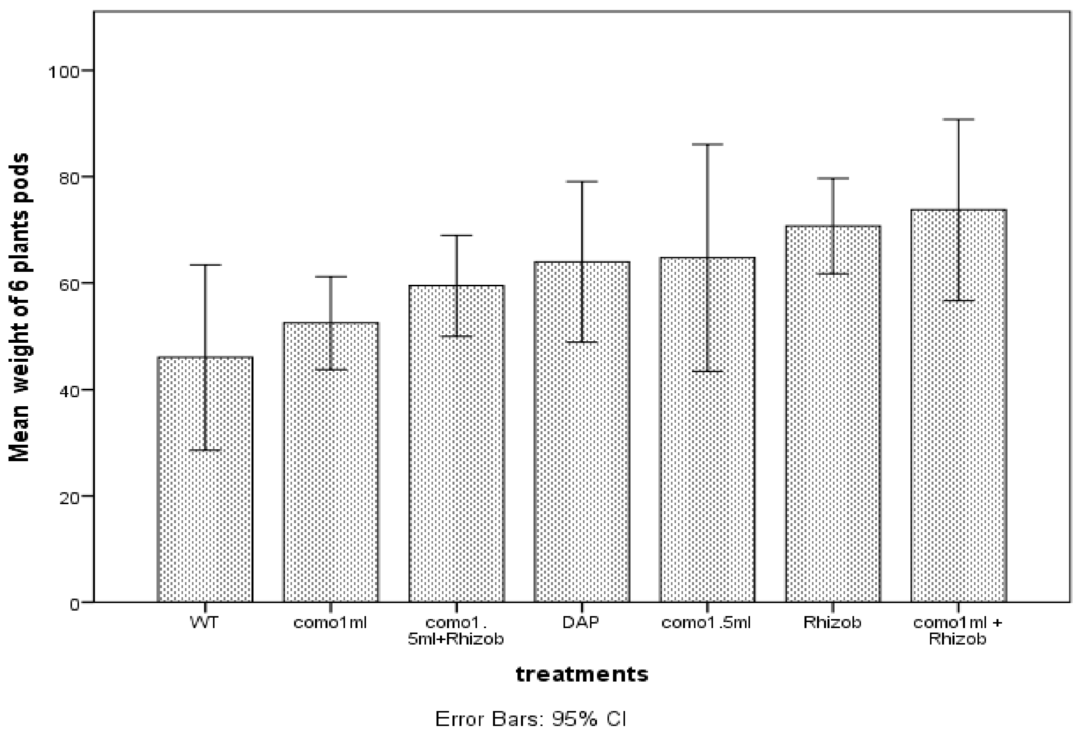


Table 4.7

ANOVA on the effect of inoculants on pod weight

Dependent Variable: weight of 6 plants pods

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.
Block	167.207	1	167.207	2.040	.169
Treat	2310.429	6	385.071	4.699	.004
Error	1639.043	20	81.952		
Total	4116.679	27			

ANOVA indicated a significant difference in pod weights among the treatments P value (0.004 <0.05).

The treatment's WT(control) (a) and CoMo1ml (ab) in pod weight had lowest pod weight, CoMo1.5ml+Rhizob, DAP, CoMo1.5ml(ac) had averagely weight of pods , CoMo1ml+Rhizob had the Highest (c) in weight of pods indicating they are statistically different among the other treatments in pod weight shown in table 4.7. Post hoc test was done and the results shown in table 4.8

Table 4.8

DMRT for pod weight per plant

Treatments	Subsets
WT(control)	46.00a
COMO1ml	52.00ab
COMO1.5ml + Rhizob	59.50abc
DAP	64.00bc
COMO1.5ml	64.75bc
Rhizob	70.75c
COMO1ml+Rhizob	73.75c
Sig.	0.063

Means difference significant at the .05 level

Pod count and weight in a plant is an essential growth parameter in in soya beans and may be significant in defining performance of plants during growing period after harvest (Heidarzade & Abbasi, 2016) Effect of inoculants on pod weight in soya beans has been evidently demonstrated in may research studies undertaken. One such study showed that use of *Bradyrhizobium japonicum* considerably produced a high number of pods and also increased its weight. Averagely, the weight of pods was 3.92% more than the control. Moreover, the study depicted that use of two inoculants would yield better than a single inoculant (Marinković et al., 2018). Similarly, Lamptey et al., (2014) revealed that there was a significant 49% up thrust in the average mean count of pods per plant and 38% rise in average pod weight per plant resulting from rhizobium treatment.

Even under drought conditions, administration of molybdenum in soya influenced pod count among other parameter. In a field experiment done in years (2017 & 2018) using *Bradyrhizobium Japonicum.* The test on the growth of soya beans confirmed increase in number of pods per plant. This indicates that use of rhizobium can significantly improve yield of soya beans in Kisii (Jarecki & Bobrecka-Jamro, 2019). These results agree with that ofGad et al., (2013) where cobalt exhibited substantial outcome on number of pods per plant, which would also influence the weight of pods in the plants measured.

4.5 Effects of different levels of cobalt/molybdenum, rhizobium inoculants and diammonium phosphate fertilizer on six plants seed weight

The harvested six tagged plants per plot, treatment were shelled and the seeds sundried to average moisture content of 13%. They were then weighed in grams using an electronic weighing balance. The Rhizobium treatment had the highest seed weight per plant whereas CoMo1ml had the least weight (Figure 4.3). Further analysis was subjected to ANOVA to identify any significant differences between treatments. Results are as shown in table 4.9

Figure 4.3

Mean six plants seed weight

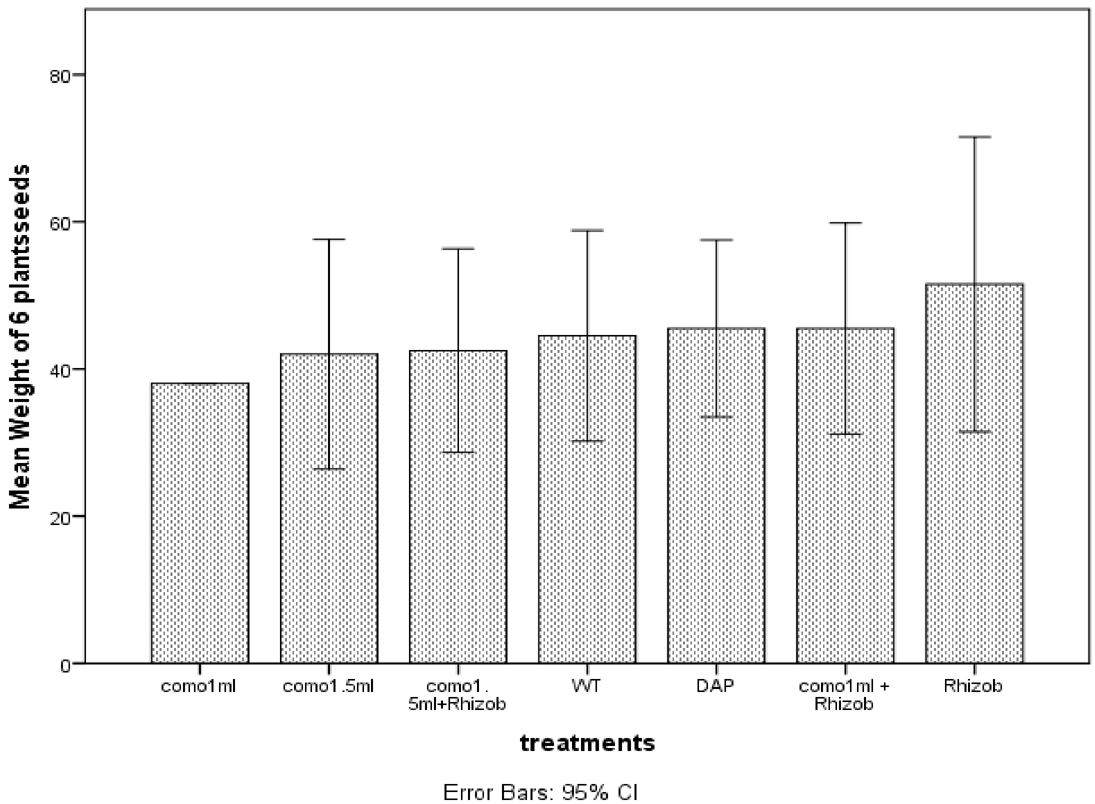


Table 4. 9

ANOVA on the effect of inoculants on seed weight per six plants

Dependent Variable: Weight of 6 plants seeds

Source	**Type III Sum of Squares**	**Df**	**Mean Square**	**F**	**Sig.**
Block	418.714	3	139.571	2.045	.144
Treat	411.714	6	68.619	1.006	.452
Error	1228.286	18	68.238		
Total	2058.714	27			

a. R Squared = .403 (Adjusted R Squared = .105)

ANOVA indicated no significant difference among the treatments P (0.4520>0.050).

According to Gad et al., (2013) the weight of seeds per plant measured was seen to have been influenced by cobalt treatment. Co-inoculated with DAP, there was a significant increase in weight of seeds. Similarly, administration of rhizobium combined with nitrogen exhibited increased seed weight. This shows that seed development and pod filling is promoted by nitrogen availability. In this case, rhizobium, N plus the P nutrients in soil facilitate BNF resulting to result in the generation of amino acids and proteins which boosts the development of increases seeds and the pods are completely filled (Herliana et al., 2019).

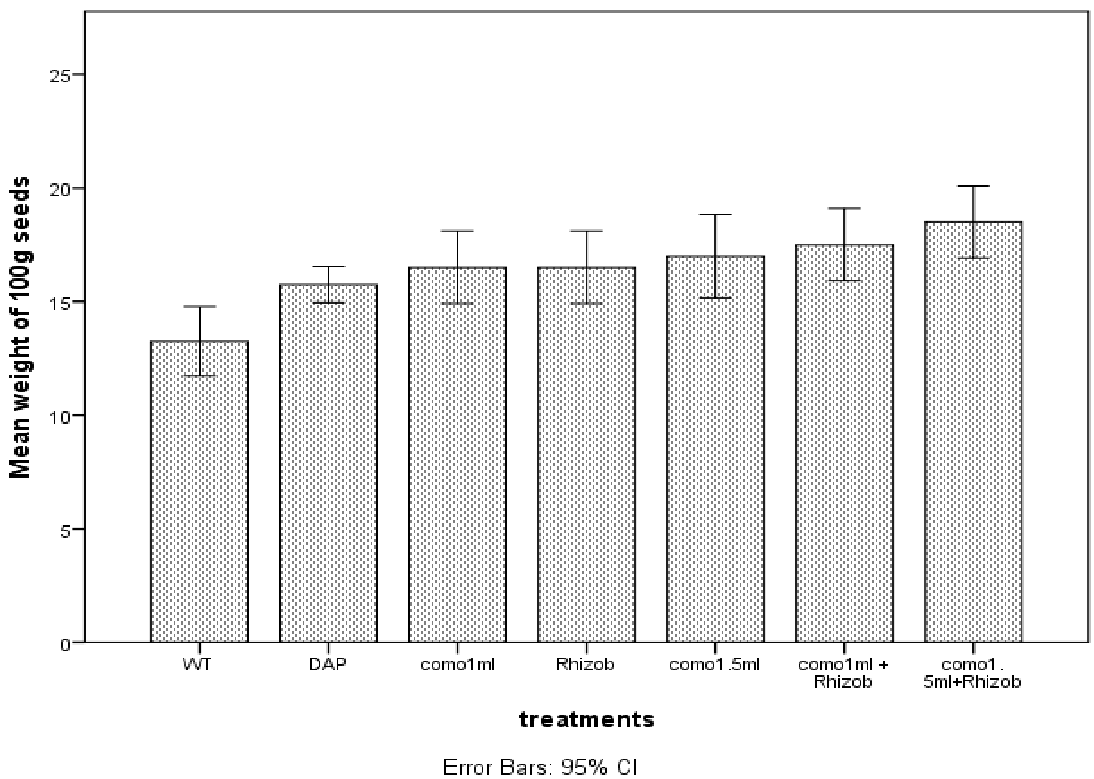
Further, in a report published by Alam, et al., (2015) , the results supported other findings on seed weight per plant by demonstrating that pre inoculated plants with Rhizobium sp. had improved seed yield than non-inoculated plants in the study. This is congruence with other inoculants that showed higher seed weight per plant indicating that inoculants efficiently executes synergistic relationship in a variety soybean thus influencing increasing different yield parameters (Carlos et al., 2019; Lamptey et al., 2014b; Marinković et al., 2018)

4.6 Effects of different levels of cobalt/molybdenum, rhizobium inoculants and diammonium phosphate fertilizer on 100 seeds weight

100 seeds per treatment were randomly picked, counted and weighed. This was a proxy measure to determine the effect of treatments on grain filling and density. The data so collected was collated and recorded for statistical analysis. Among treatments in figure 4.4, CoMo1.5ml+Rhizob had the highest, and control the least effect on weights.

Figure 4.4

Mean weight of 100 seed weight



ANOVA indicated significant difference of 100weight seeds among the treatments, P value (< 0.001) the results were further subjected to post hoc test results as indicated in table 4.10

Table 4.10

ANOVA on the effect of inoculants on 100 seed weight in grams

Dependent variable: 100 seed weight in grams

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.
Block	5.143	3	1.714	2.149	.130
Treat	65.357	6	10.893	13.657	.000
Error	14.357	18	.798		
Total	84.857	27			

Available information on the effect of cobalt on seed weight in different graded level of (0, 50, 100, 150, 200 and 250 mg kg-1soil) showed a gradual increase in the weight of 100 seeds with increase in cobalt levels. However, least weight was seen in level of 100 mg kg level onwards (Jayakumar et al., 2009). It is worth worthy to note that cobalt in high concentration is toxic thus affecting plant growth. In general soya beans fail to respond to higher levels of inoculants in general (Neto et al., 2017b)

Table 4.11

DMRT Comparison of 100 seed weight in grams under different treatments

Treatment	Subsets
Control (WT)	13.2500 a
DAP	15.7500b
CoMo1	16.5000 bc
Rhizob	16.5000bc
CoMo1.5	17.0000bc
CoMo1+Rhizob	17.5000cd
CoMo1.5+Rhizob	18.5000d
Sig.	

Means difference significant at the .05 level

The weight of 100 seed for the control (WT) treatment (a) had the least 100 seed weight and statistically different from all other treatments, Treatments DAP sub set (b), CoMo1. Rhizob and CoMo1.5 (bc) were in same level indicating their average weights were almost the same, and were different from CoMo1.5 + Rhizob (d)which was highest in 100 seed weight.

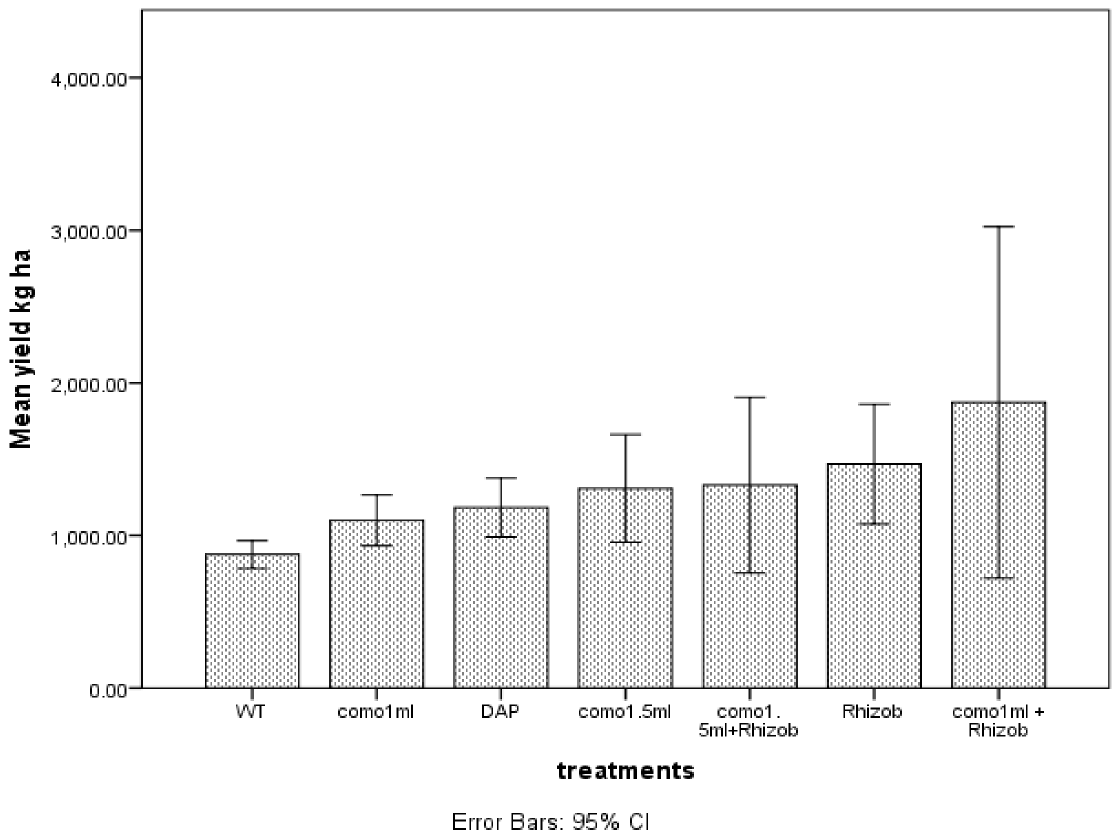
A study to investigate cobalt use at 12 mg kg-1 on soya beans revealed that, all yield characteristics were increased. In combination with ammonium nitrate, 100 seed weight was observed to improve (Kandil et al., 2013). Rhizobium equally exhibited increased 100 seed weight in an experiment conducted India by Herliana et al., (2019). Even though single administration of inoculants show significant effect on seed weight, Marinković et al., (2018), urges co inoculation with rhizobium is essential for better soybean yield since many studies have shown highest yields with combination of inoculants.

4.7 Effects of different levels of cobalt/molybdenum, rhizobium inoculants and diammonium phosphate fertilizer on yield in kg per ha.

At maturity all plants per treatment (per plot) were collected, sundried, prepared and sorted. It was then sundried at moisture content of 13%, weighed and the data collated and recorded for statistical analysis. The weight was measured in kilograms per acre. The mean yield in kg per for each treatment are as shown in figure 4.5

Figure 4.5

Mean yields in kilograms hectare



The highest yielding inoculation treatment was CoMo1ml+Rhizob followed closely by Rhizob. The treatments WT (control) had the lowest grain yields, as indicated in fig.4.7. The treatments collected data were subjected to ANOVA test, the means different treatments result of yields are shown in table 4.12

Table 4.12

ANOVA on the effect of inoculants on yields kg ha

Dependent variable: yield kg ha

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.
Treat	2363076.929	6	393846.155	3.470	.015
Error	2383480.500	20	113499.071		
Total	4746557.429	27			

a. R Squared = .498 (Adjusted R Squared = .354)

ANOVA showed a significant difference among the treatment's yield per ha P (0.015>0.05).

The DMRT indicates that the (WT) control(a) has the least yields, followed by CoMo1m and DAP (ab), CoMo1.5ml +Rhizob, CoMo1.5ml, and Rhizob (bc) had more yields but CoMo1.5ml +Rhizobium, have the highest yields and different from the rest of the treatments. Post hoc test is shown in the table 4.13

Table 4.13

DMRT for grain yield in kilograms per ha

Treatments	**Sub set**
WT	875.0000a
CoMo1ml	1099.5000ab
DAP	1183.2500ab
CoMo1.5ml+Rhizob	1308.5000ab
CoMo1.5ml	1308.5000ab
Rhizob	1467.5000bc
CoMo1ml + Rhizob	1872.2500c
Sig.	.104

Means difference significant at the .05 level

In 2018, an estimated 121.53 million hectares of land globally was used for soya bean cultivation, with 2.76 tones ha-1 while the total yield was 334.89 million tones (Terzic et al., 2018). Approaches to increase yield of soya due to the global demand and economic gain has pushed countries to explore alternative ways of improvement. Use of inoculant to improve yield has been documented to be effective and now very competitive. In a study to foliar use of molybdenum on the yield parameters of soya beans in Iran, the findings revealed that under water deficient environments, use of molybdenum increased yield. Association between treatments portrayed. The author added by suggesting that inoculants application is environmentally friendly, causes no pollution and a favorable approach to boosting yield (Heidarzade & Abbasi, 2016).

The findings of this study is supported by Galindo et al., (2017), the results exhibited increased yield when Co + Mo and A. *brasilense* were used in soya bean . The average yield in sacks was almost seventeen sacks more than the control. Similarly, it was also observed that rhizobium used in soybeans improved yield. Inoculant coated crops generated yield that was 35% higher than non-coated ones. In the same study however, fertilizer did not show a difference in not yield. It was therefore suggested that application of 4 tons per hectare of fertilizers co administered with rhizobium could be better agronomic strategy for improvement of quality and total in soya beans (As et al., 2017a). In Siaya, an experiment testing use of Legumefix + Sympal + urea showed a considerable improvement in yield (475, 709, 856, 880, 966 kg ha− (Mathenge et al., 2019a). The potential to produce high yield per hectare at 4–6 t ha−1 is possible with good agronomic practices, ecological zone and soil conditions (Takahashi, 2020).

4.8 Effects of different levels of cobalt/molybdenum, rhizobium inoculants and diammonium phosphate fertilizer on number of branches at harvest

Number of branches of the plants with different treatments were counted and recorded during harvesting time. The ANOVA indicated no significant difference in the number of branches among various treatment's P value (0 .817 >0.05). No further analysis was done.

Table 4. 14

ANOVA on the effect of inoculants on number of branches at harvest

Dependent Variable: number of branches at harvest

Source	**Type III Sum of Squares**	**Df**	**Mean Square**	**F**	**Sig.**
Block	.961	1	.961	1.611	.219
Treat	1.759	6	.293	.491	.807
Error	11.934	20	.597		
Total	14.654	27			

a. R Squared = .186 (Adjusted R Squared = -.099)

The number of branches in crops is a measure of growth parameter. This study showed no significant difference in the number of branches among treatment. However, findings from a study done by Gad et al., 2013, demonstrated that cobalt inoculant promoted growth of soya beans. From the study, cobalt at 12ppm, exhibited the highest branch count per plant compared to the other. Such observations imply that increasing the quantity decreases the effect. Many studies have document increased growth parameters with application of inoculants in soya beans. Studies have explained that growth is promoted by effective BNF result from adequate supply of nitrogen and subsequent symbiotic relationship in soil with rhizobia.

4.9 Effects of different levels of cobalt/molybdenum, rhizobium inoculants and diammonium phosphate fertilizer on number of pods at harvest

Pods count per the tagged plants for each treatment, were counted during harvest and data recorded. The number of pods was high in CoMo1ml + Rhizob treatment compared to other treatments, Rhizob and CoMo1.5ml+Rhizob was the least

Table 4.15

ANOVA on the effect of inoculants on the number pods at harvest

Dependent Variable: number of pods at harvest

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.
Block	26.928	1	26.928	1.231	.280
Treat	34.842	6	5.807	.266	.947
Error	437.347	20	21.867		
Corrected Total	499.117	27			

a. R Squared = .124 (Adjusted R Squared = -.183)

The treatments were subjected to analysis of ANOVA results indicated there was no significant difference in number of pods after harvest among treatment's the, P value (0.948 >0.05)

The successful growth of legumes is portrayed by the number of pods a plant produces. Various studies have reported increased number of pods in plants even in different water conditions. Evaluation of soya beans growth in water deficient environment demonstrated positive effect on the number of pods (Heidarzade & Abbasi, 2016). In a different study, rhizobium treated plots exhibited top most pod number, weight and high yield (50.80grams and 843kilgrams per hectare) the increase was a significantly significant compared to the inoculated seeds (Lamptey et al., 2014b).Reports from another study by Herliana et al., (2019), rhizobium on ANOVA exhibited significant difference on weight and number of pods compared to the other treatments. Such evidence confirm that bacterial microorganism interacting with nodules promote soybean crops in pod formation. Additionally, the authors stated pod count is mainly promoted by vegetative development involving the rate of photosynthesis rate and uptake.

4.10 Effects of different levels of cobalt/molybdenum, rhizobium inoculants and diammonium phosphate fertilizer on plant height at harvest

The height of soybean plants was taken from the 6 tagged plants at maturity stage, just before the beans were harvested, of different treatments in 4 blocks and their mean average was taken and recorded.

Figure 4.6

Mean plant height at harvest

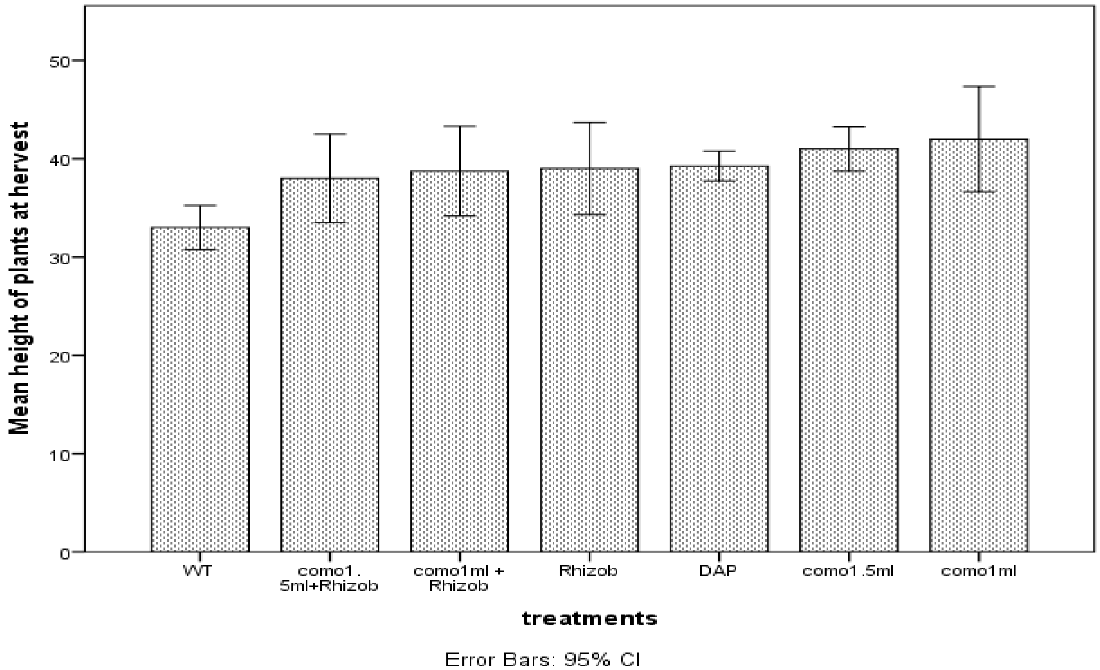


Table 4.16

ANOVA on the effect of inoculants on plant height at harvest.

Dependent Variable: height of plants at harvest

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.
Block	15.114	1	15.114	2.789	.110
Treat	198.214	6	33.036	6.096	.001
Error	108.386	20	5.419		
Total	321.714	27			

a. R Squared = .663 (Adjusted R Squared = .545)

ANOVA results indicated a significant difference in plant heights at harvest among treatments p (0.001 <0.05).

Table 4. 17

DMRT for height of plants at harvest

Treatments	Subset
WT	33.00a
CoMo1.5ml+Rhizob	38.00b
CoMo1ml + Rhizob	38.75bc
Rhizob	39.00bc
DAP	39.25bc
CoMo1.5ml	41.00bc
CoMo1ml	42.00c
Sig.	1.000

Means difference significant at the .05 level

WT (Control) treatment had the shortest plants average height 33cm, Rhizob and DAP had 39cm, while CoMo 1ml was the highest, 42cm height which was the tallest plants. Single application using rhizobium in soya bean cultivars was shown to slightly increase the plant height. The tallest plant documented was 35.12cm different from the control which was 34.25cm (Lamptey et al., 2014b). This was also in congruent with findings from a different study where molybdenum was co inoculated with N and P. The plant height was reported when 60 kg N/fed and 13.1 kg P/fed was used (Glal , 2016)

4.11 Effects of different levels of cobalt/molybdenum, rhizobium inoculants and diammonium phosphate fertilizer on number of leaves at maturity

Numbers of Leaves were counted on the 6 tagged plants per treatments per block and their average numbers recorded, from time of emerging to maturity before harvesting.DAP and CoMo1ml had the highest average number of leaves per plant compared to the other treatments, Rhizob and WT (control) had the least numbers of leaves.

Table 4.18

ANOVA on the effect of inoculants on number of leaves at harvest

Dependent variable: number of leaves

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.
Block	12.480	1	12.480	1.515	.233
Treat	32.854	6	5.476	.665	.679
Error	164.735	20	8.237		
Corrected Total	210.069	27			

a. R Squared = .216 (Adjusted R Squared = -.059)

The treatments were subjected to ANOVA and the results indicated no significant difference in number of leaves at harvest P value (0.679 >0.05).

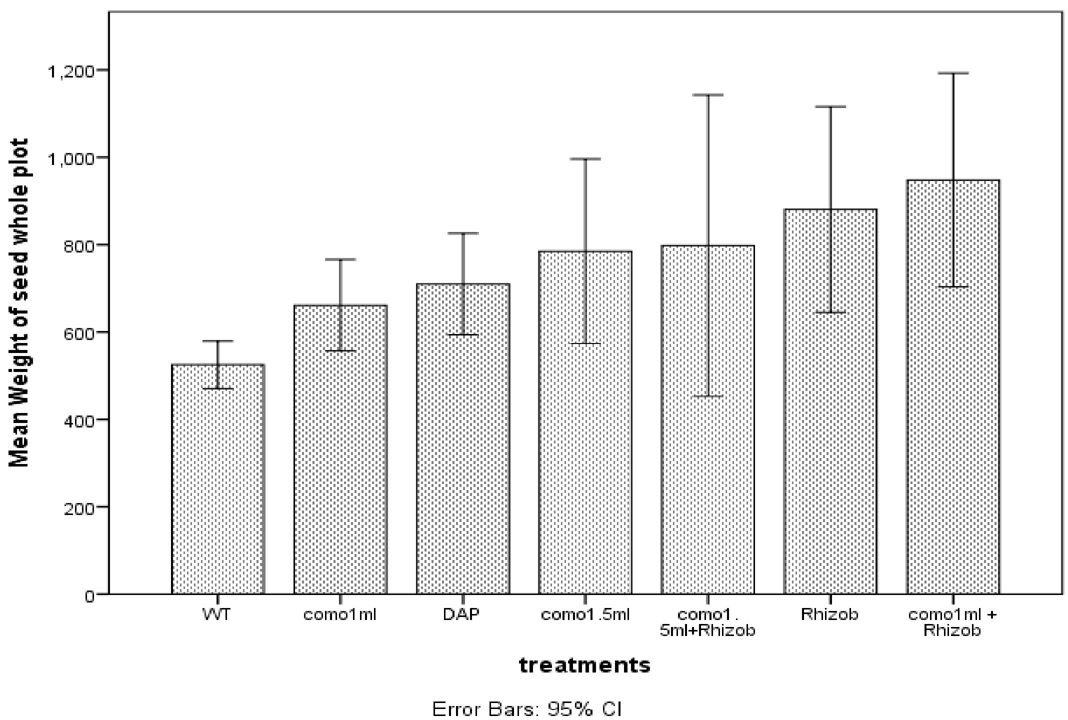
Contrary to the findings from this study, an experiment done in Nigeria showed that rhizobium was significant in leaf count (As et al., 2017b). Many studies have not dwelt on evaluating effect of inoculants on leaf count in soya beans. The studies have described leaf area, and have documented significant positive influence on surface area of soya beans with application of inoculants (Lamptey et al., 2014b). Generally, Herliana et al.,(2019), confirmed that rhizobia had a significant effect on the number of leaves in soya beans.

4.12 Effects of different levels of cobalt/molybdenum, rhizobium inoculants and diammonium phosphate fertilizer on weight of seeds the whole plot

The soya seeds were harvested for each treatment per plot in the replicated blocks, dried at moisture13% and winnowed, average weight for each treatment as taken and data recoded and results shown in the figure 4.7. The weight of seeds was shown to be high on COMO1ml+Rhizob treatment, followed by Rhizob, and the least weight was WT (control).

Figure 4.7

Weight of seed whole plot



The weight of seeds was shown to be high on CoMo1ml/Rhizob treatment, followed by Rhizob, and the least weight was WT (control)

Table 4.19

ANOVA on the effect of inoculants on weight of seeds whole plot

Dependent variable: weight of seeds whole plot

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.
Block	10841.600	1	10841.600	.615	.442
Treat	477272.929	6	79545.488	4.515	.005
Error	352323.900	20	17616.195		
Total	840438.429	27			

R Squared = .581 (Adjusted R Squared = .434)

The treatments were subjected to ANOVA, the results indicated a significant difference in the weight of seeds at harvest P value (0.005 <0.05).

Further Post hoc analysis (Table 4.20) showed, WT (Control) treatment had the least seed weight, the highest weight was seen with CoMo1ml+Rhizob

Table 4.20

DMRT for weight of seed the whole plot.

Treatments	Subsets
CoMo1ml	661.50ab
DAP	710.00ab
CoMo1.5ml	785.00bcd
CoMo1.5ml+Rhizob	798.00bcd
Rhizob	880.50cd
CoMo1ml + Rhizob	948.25d

Means difference significant at the .05 level

Many studies have reported on yield in kilograms per hectare. Generally, inoculants such as Bradyrhizobium has demonstrated significant increase in seed weight (p<0.01)(Solomon et al., 2012). As evidently discussed by several authors on positive effectives of rhizobia, cobalt and molybdenum on soya beans growth and yield, it is therefore possible to assume that seed weight in a whole plot can equally be influenced especially in co inoculation as depicted by the current study.

CHAPTER FIVE

SUMMARY, CONCLUSIONS AND RECOMMENDATION

5.1Introduction

This section summarizes the research findings, conclusion and recommendations based on study findings. The study aimed at examining the effects of diammonium phosphate fertilizer, cobalt/molybdenum (CoMo), and rhizobium inoculants on the growth and yields of soya beans in Kisii County. The objectives were to assess the effects of CoMo inoculants, analyze rhizobium inoculants and evaluate their interaction in various rates on the growth and yield of soya beans.

5.2 Summary of the findings

The availability of nitrogen and phosphorus nutrients in the soil is essential in the soya beans cultivation as it significantly affect its growth and yield. Use of inoculants as an alternative to improving soya bean productivity was shown to significantly affect all the growth and yield parameters of cultivars in the study. The type of inoculants and the pH of soil affect productivity of soya beans. Preliminary soils analysis showed adequate levels of organic carbon (2.4%), phosphorus (20 ppm) and nitrogen (0.12ppm). Soil pH was 5.5, while Co and Mo levels were 54.6 Mg/lg and 6.44 Mg/lg respectively.

There was a statistically significant difference between treatments ($p<0.05$) on germination percentage, 50 % flowering, pod weight per plant, 100weight seeds, yield per hectare, height of plants and weight of seeds the whole plot. Plots under CoMo1.5ml + Rhizob or CoMo 1 ml + Rhizobia treatment depicted highest performance for all growth and yield parameters studied. Analysis did not show any statistical difference on above ground plant biomass and seed weight per plant. Plots with DAP and without treatment exhibited minimal effect on all growth and yield variables analyzed. Single application of rhizobium had the least effect compared to when combined with CoMo.

As explained in many research studies, application of inoculants during planting enhances the growth and yield parameters of the soybean. Improved growth and grain yield has been attributed to increased symbiotic relationship of rhizobia (bacteria) with the roots of soya crops resulting to increased fixation of atmospheric nitrogen increasing uptake and accessibility of nutrients to the plants (Sylvain, 2020).

5.3 Conclusions

a) Soya beans are among very important legumes, production is important for both sustenance and economic gains of the country. The findings from this study indicate that soil in Kisii is moderately acidic and has low nitrogen and phosphorus levels, important in nitrogen fixation in plants. Use of combinations of inoculants was shown to influence growth of soya beans. CoMo and Rhizobium inoculants at either 1ml CoMo or 1.5mls CoMo was shown have the highest effect compared to other treatments.

b) Inoculation is effective in enhancement of rhizobia, which subsequently aids in crop growth and soil fertility. Interaction of cobalt, molybdenum and rhizobium showed significant effect on all growth and yield parameters of soya beans. Combination of inoculants prior to planting of soya beans in Kenya is an effective method to increase yield of soya beans. It can then be concluded that inoculants effectively influence parameters such as; six plants pod weight, 100 seed weight, and yield per hectare among others. Commitment from the government in the achievement of sustainable agricultural systems and realization of the sustainable development goals is important. Access to high quality soya beans products and utilization of bacterial inoculants by local farmers is anticipated to potentially increase in future (Carlos & Echer, 2019).

5.4 Recommendation

Based on the findings of the study, the following are suggested:

a) To improve the yields of soya beans in Kisii, use of combined inoculant Cobalt/Molybdenum and Rhizoliq by seed dressing is recommended.

b) The agricultural extension workers in Kisii County should educate farmers on the use of combined inoculants in soya bean farming, at the same time emphasizing on use of improved certified seed varieties

c) The ministry of Agriculture through the counties to provide affordable seeds and inoculants to encourage farmers plant soya beans in larger fields. This will meet the growing demand for food and industrial use among the populace in Kenya.

5.5 Research output.

Part of the results on yield was disseminated through a conference presentation and publication of an article in the International Journal for Research in Agricultural and Food Science.

Areas of further research recommended include:

a) Evaluate the effect of CO and MO inoculants separately and individually on the growth and yield of soya beans

b) Investigate effects of nitrogen and phosphorus levels on soya bean production.

REFERENCE

Alam, F., Bhuiyan, M. a. H., Alam, S. S., Waghmode, T. R., Kim, P. J., & Lee, Y. B. (2015). Effect of Rhizobium sp. BARIRGm901 inoculation on nodulation, nitrogen fixation and yield of soybean (Glycine max) genotypes in gray terrace soil. *Bioscience, Biotechnology, and Biochemistry*, *79*(10), 1660–1668. https://doi.org/10.1080/09168451.2015.1044931

Alam, F., Kim, T. Y., Kim, S. Y., Alam, S. S., Pramanik, P., Kim, P. J., & Lee, Y. B. (2015). Effect of molybdenum on nodulation, plant yield and nitrogen uptake in hairy vetch (Vicia villosa Roth). *Soil Science and Plant Nutrition*, *61*(4), 664–675. https://doi.org/10.1080/00380768.2015.1030690

Araujo, R. S., Cruz, S. P. da, Souchie, E. L., Martin, T. N., Nakatani, A. S., Nogueira, M. A., & Hungria, M. (2017). Preinoculation of Soybean Seeds Treated with Agrichemicals up to 30 Days before Sowing: Technological Innovation for Large-Scale Agriculture. *International Journal of Microbiology*, *2017*(*5914786)*, 1–11. https://doi.org/10.1155/2017/5914786

Argaw, A. (2016). Effectiveness of Rhizobium inoculation on common bean productivity as determined by inherent soil fertility status. *Journal of Crop Science and Biotechnology*, *19*(4), 311–322. https://doi.org/10.1007/s12892-016-0074-8

As, A., Ao, T., Ab, O., & Wb, A. (2017). Effect of Fertilizer and Rhizobium Inoculation on Growth and Yield of Soyabean Variety (Glycine max L. Merrill). *Advances in Crop Science and Technology*, *5*(1), 1–9. https://doi.org/10.4172/2329-8863.1000255

Asante, M., Ahiabor, B. D. K., & Atakora, W. K. (2020). *Growth, Nodulation, and Yield Responses of Groundnut (Arachis hypogaea L.) as Influenced by Combined Application of Rhizobium Inoculant and Phosphorus in the Guinea Savanna Zone of Ghana*. Hindawi International Journal of Agronomy, 7(1), 121–129. https://doi.org/10.1155/2020/8691757

Asei, R., Ewusi-Mensah, N., & Abaidoo, R. (2015). Response of Soybean (Glycine max L.) to Rhizobia Inoculation and Molybdenum Application in the Northern Savannah Zones of Ghana,. *Journal of Plant Science, 3(2)*, 64–70. https://doi.org/10.11648/j.jps.20150302.14

Assenga, O., Feyissa, T., & Ndakidemi, P. (2016). Quantifying the Occurrence and Ameliorating the Properties of Non-responsive Soils by Inorganic and Organic Fertilizers. *International Journal of Plant & Soil Science*, *9*(4), 1–19. https://doi.org/10.9734/IJPSS/2016/13928

Campo, R. J., Araujo, R. S., Mostasso, F. L., & Hungria, M. (2010). In-furrow inoculation of soybean as alternative to fungicide and micronutrient seed treatment. *Revista Brasileira de Ciência do Solo*, *34*(4), 1103–1112. https://doi.org/10.1590/S0100-06832010000400010

Carlos Felipe Cordeiro, dos S., & Echer, F. R. (2019). Interactive Effects of Nitrogen-Fixing Bacteria Inoculation and Nitrogen Fertilization on Soybean Yield in Unfavorable Edaphoclimatic Environments. *Scientific Reports*, *9*(1), 1–11. https://doi.org/10.1038/s41598-019-52131-7

Cordeiro, C. F. dos S., & Echer, F. R. (2019). Interactive Effects of Nitrogen-Fixing Bacteria Inoculation and Nitrogen Fertilization on Soybean Yield in Unfavorable Edaphoclimatic Environments. *Scientific Reports*, *9*(1), 1–11. https://doi.org/10.1038/s41598-019-52131-7

Crusciol, C. A. C., Ferrari Neto, J., Mui, T. S., Franzluebbers, A. J., Costa, C. H. M. da, Castro, G. S. A., Ribeiro, L. C., Costa, N. R., Crusciol, C. A. C., Ferrari Neto, J., Mui, T. S., Franzluebbers, A. J., Costa, C. H. M. da, Castro, G. S. A., Ribeiro, L. C., & Costa, N. R. (2019). Rhizobial Inoculation and Molybdenum Fertilization in Peanut Crops Grown in a No Tillage System after 20 Years of Pasture. *Revista Brasileira de Ciência do Solo*, *43*(e0170399), 1-19 https://doi.org/10.1590/18069657rbcs20170399

Darwesh, D., A., Amin, S. A., & Maulood, P., M. (2013). Effect of Phosphorus Fertilizers on Growth and Physiological Phosphorus Use Efficiency of Three Soy Bean Cultivars. *IOSR Journal of Agriculture and Veterinary Science*, *3*(6), 32–36. https://doi.org/10.9790/2380-0363236

Etopobong, J. (2017). *Response of Promiscuous Soybean to Rhizobial Inoculation in Combination with Organic and Mineral Fertilizers in Some Soils of The Nigerian*

Guinea Savanna [Master's thesis]. Federal University of Technology Minna https://n2africa.org/sites/default/files/Dissertation%20EKAETTE%20FUT%20Minna.pdf

FarmBiz. (2018). *Drought tolerant soy bean can earn farmers Sh170,000 in three months*. https://farmbizafrica.com/advertise/13-high-yield/2364-drought-tolerant-soy-bean-can-earn-farmers-sh170-000-in-three-months-2

Ferri, G., Braccini, A., Fernanda, B., & Caiubi, L. (2017). Effects of associated co-inoculation of Bradyrhizobium japonicum with Azospirillum brasilense on soybean yield and growth. *African Journal of Agricultural Research*, *12(3)*, 6–11. https://doi.org/10.5897/AJAR2016.11711

Filho, M. C. M. T., Shintate Galindo, F., Buzetti, S., & Santini, J. M. K. (2017). Inoculation with Bradyrhizobium sp. And Azospirillum brasilense Associated with Application of Cobalt and Molybdenum on Nutrition and Soybean Yield In M. Kasai (Ed.), *Soybean - The Basis of Yield, Biomass and Productivity*, IntechOpen, https://doi.org/10.5772/66572.

Gad, N., El-Moez, A., Bekbayeva, L. K., Karabayeva, A. A., & Surif, M. (2013). Effect of Cobalt Supplement on the Growth and Productivity of Soybean (Glycine max L.Merril).*World Applied Sciences Journal 26*(7), 926-933, https://doi.org/10.5829/2013.26.07.13524

Galindo, F. S., Teixeira Filho, M. C. M., Buzetti, S., Santini, J. M. K., Ludkiewicz, M. G. Z., Baggio, G., Galindo, F. S., Teixeira Filho, M. C. M., Buzetti, S., Santini, J. M. K., Ludkiewicz, M. G. Z., & Baggio, G. (2017). Modes of application of cobalt, molybdenum and Azospirillum brasilense on soybean yield and profitability. *Revista Brasileira de Engenharia Agrícola e Ambiental*, *21*(3), 180–185. https://doi.org/10.1590/1807-1929/agriambi.v21n3p180-185

Gikonyo, E. W., Cisse, L., Mangale, N., Mumbua, A., & Kibunja, C. (2014a). Efficacy of Two Sulphur Fertilizers on Some Crops in Smallholder Farming in Kenya. *Procedia Engineering*, *83*, 354–364. https://doi.org/10.1016/j.proeng.2014.09.028

Gikonyo, E. W., Cisse, L., Mangale, N., Mumbua, A., & Kibunja, C. (2014b). Efficacy of Two Sulphur Fertilizers on Some Crops in Smallholder Farming in Kenya. *Procedia Engineering*, *83*(2014), 354 – 364. https://doi.org/10.1016/j.proeng.2014.09.028

Glal O. A. (2016). Effect of rhizobium inoculation under bio- and mineral fertilization and their interaction on quality and quantity of soybean. J*ournal of Soil Sciences and Agricultural Engineering*, *7*(11) 809-827. https://doi.org/10.21608/jssae.2016.40482

Hankinson, M. W., Lindsey, L. E., & Culman, S. W. (2015). Effect of Planting Date and Starter Fertilizer on Soybean Grain Yield. *Crop, Forage & Turfgrass Management*, 1(1), https://doi.org/10.2134/cftm2015.0178

Hc, O., & Aa, U. (2019). *Influence of Nodumax Inoculant on Nodulation, Root Growth Parameters of Soybean and Soil Physico-Chemical Properties*. EC Agriculture 5(10), 619-627. https://www.ecronicon.com/ecag/pdf/ECAG-05-00208.pdf

Heidarzade, A., & Abbasi, R. (2016). Response of soybean (Glycine max) to molybdenum and iron spray under well-watered and water deficit conditions. *Journal of Experimental Biology and Agricultural Sciences*, *4*(1), 37–46. https://doi.org/10.18006/2015.4(1).37.46

Herliana, O., Harjoso, T., Anwar, A. H. S., & Fauzi, A. (2019). The Effect of Rhizobium and N Fertilizer on Growth and Yield of Black Soybean (Glycine max (L) Merril). *Institute of Research and Community Service*, *255*(012015), 1-7. https://doi.org/10.1088/1755-1315/255/1/012015

Ibrahim Dagash, Y. (2015). The Effects of Rhizobium, Mycorrhizal Inoculations and Diammonium Phosphate (DAP) on Nodulation, Growth, and Yield of Soybean. *Universal Journal of Agricultural Research*, *3*. https://doi.org/10.13189/ujar.2015.030103

Jarecki, W., & Bobrecka-Jamro, D. (2019). Influence of Seed Inoculation with Commercial Bacterial Inoculants (Bradyrhizobium Japonicum) on Growth and Yield of Soybean. *Legume Research*, *42(5)*, 688–693. https://doi.org/10.18805/LR-485

Jonas, C., Vanlauwe, & B, Mahasi, JM2, Katungi E3, Akech C1, Mairura FS1, Chianu Justina N, Sanginga N. (2020). Rso-sbean-kenya.pdf. *Kenya Agricultural Research Institute*. http://www.icrisat.org/what-we-do/impi/projects/tl2-publications/regional-situation-outlook-reports/rso-sbean-kenya.pdf

Kandil, H., Farid, I., & El-Maghraby, A. (2013). Effect of Cobalt Level and Nitrogen Source on Quantity and Quality of Soybean Plant. *Journal of Basic and Applied Scientific Research.*, *3*(12), 185–192. https://www.researchgate.net/publication/283301669_Effect_of_Cobalt_Level_and_Nitrogen_Source_on_Quantity_and_Quality_of_Soybean_Plant

Kang, B. T. (2020). Effects of Inoculation and Nitrogen Fertilizer on Soybean in Western Nigeria. *Experimental Agriculture*, *11*(1), 23–31. https://doi.org/10.1017/S0014479700006190

Khojely, D. M., Ibrahim, S. E., Sapey, E., & Han, T. (2018). History, current status, and prospects of soybean production and research in sub-Saharan Africa. *The Crop Journal*, *6*(3), 226–235. https://doi.org/10.1016/j.cj.2018.03.006

Kisii County. (2019). *Features of Kisii County-Physiographic and Natural Conditions*. Kisii County Government. https://www.kisii.go.ke/index.php/county-profile/position-and-size

Kubota, A., Hoshiba, K., & Bordon, J. (2008). Effect of fertilizer-N application and seed coating with rhizobial inoculants on soybean yield in eastern Paraguay. *Revista*

Brasileira de Ciência do Solo, *32*(4), 1627–1633. https://doi.org/10.1590/S0100-06832008000400027

Lacerda, J. J. de J., Lopes, L. O., PietaRambo, T., Marafon, G., Silva, A. de O., Lira, D. N. de S., Hickmann, C., LimaDias, K. G. de, & Bottan, A. J. (2017). Soybean Yield Responses to Micronutrient Fertilizers In M. Kasai (Ed.), S*oybean - The Basis of Yield, Biomass and Productivity*, IntechOpen. https://doi.org/10.5772/67157.

Lambon, J. B. (2016). *Inoculation And N Fertilizer Effects On The Growth, Grain Yield And N Remobilization In Soybean (Gylcine Max [L] Merrill) In The Guinea Savanna Zone Of Ghana*. [Doctoral Thesis]. Jomo Kenyatta University of Agriculture and Technology. http://hdl.handle.net/123456789/9468

Lamptey, S., Ahiabor, B., S., Y., & Osei, D. (2014a). Effect of Rhizobium Inoculants and Reproductive Growth Stages on Shoot Biomass and Yield of Soybean (Glycine max (L.) Merril). *Journal of Agricultural Science*, *6*(5), 152-177. https://doi.org/10.5539/jas.v6n5p44

Lamptey, S., Ahiabor, B., S., Y., & Osei, D. (2014b). Effect of Rhizobium Inoculants and Reproductive Growth Stages on Shoot Biomass and Yield of Soybean (Glycine max (L.) Merril). *Journal of Agricultural Science*, *6*(5), 2014-2021. https://doi.org/10.5539/jas.v6n5p44

Lobo, C. B., Juárez Tomás, M. S., Viruel, E., Ferrero, M. A., & Lucca, M. E. (2019). Development of low-cost formulations of plant growth-promoting bacteria to be used as inoculants in beneficial agricultural technologies. *Microbiological Research, 219*, 12–25. https://doi.org/10.1016/j.micres.2018.10.012

Marinković, J., Bjelić, D., Tintor, B., Miladinovic, J., Đukić, V., & Djordjevic, V. (2018). *Effects of soybean co-inoculation with plant growth promoting rhizobacteria in field trial.African. Journal of Microbiology Research*, *6*(27), 5683-5690. https://e-repository.org/rbl/vol.23/iss.2/4.pdf

Mathenge, C., Thuita, M., Masso, C., Gweyi-Onyango, J., & Vanlauwe, B. (2019a). Variability of soybean response to rhizobia inoculant, vermicompost, and a legume-specific fertilizer blend in Siaya County of Kenya. *Soil & Tillage Research*, *194*(5), 125-145. https://doi.org/10.1016/j.still.2019.06.007

Mathenge, C., Thuita, M., Masso, C., Gweyi-Onyango, J., & Vanlauwe, B. (2019b). Variability of soybean response to rhizobia inoculant, vermicompost, and a legume-specific fertilizer blend in Siaya County of Kenya. *Soil and Tillage Research*, *194*(5), 115-145. https://doi.org/10.1016/j.still.2019.06.007

Meena, R. S., Vijayakumar, V., Yadav, G. S., & Mitran, T. (2018). Response and interaction of Bradyrhizobium japonicum and arbuscular mycorrhizal fungi in the soybean rhizosphere. *Plant Growth Regulation*, *84*(2), 207–223. https://doi.org/10.1007/s10725-017-0334-8

Mrkovacki, N., Marinković, J., & R, A. (2008). Effect of N Fertilizer Application on Growth and Yield of Inoculated Soybean. *Advances in Crop Science and Technology, 36*(1), 145-165. https://doi.org/10.15835/nbha36190

Neto, S., Pires, F., Madalão, J., Viana, D., Menezes, C., & Assis, R. (2017). Growth and yield performance of soybean with the application of Bradyrhyzobium inoculant via furrow and seed. *Brazilian Journal of Soil Science, 38(1),* 2387-2398, https://doi.org/10.5433/1679-0359.2017v38n4SUPLp2387

Neto, S., Pires, F., Menezes, C., Menezes, J., Silva, A., Silva, G., & Assis, R. (2008). Forms of inoculant application and effects on soybean nodulation. *Brazilian Journal of Soil Science, 32(2),* 861–870. https://doi.org/10.1590/S0100-06832008000200040.

Ohyama, T., Tewari, K., Ishikawa, S., Tanaka, K., Kamiyama, S., Ono, Y., Hatano, S., Ohtake, N., Sueyoshi, K., Hasegawa, H., Sato, T., Tanabata, S., Nagumo, Y., Fujita, Y., & Takahashi, Y. (2017). Role of Nitrogen on Growth and Seed Yield of Soybean and a New Fertilization Technique to Promote Nitrogen Fixation and Seed Yield. In M. Kasai (Ed.), *Soybean—The Basis of Yield, Biomass and Productivity*. InTech. https://doi.org/10.5772/66743

Pedrozo, A., Girelli de Oliveira, N. J., Alberton, O., Pedrozo, A., Girelli de Oliveira, N. J., & Alberton, O. (2018). Biological nitrogen fixation and agronomic features of soybean (Glycine max (L.)Merr.) crop under different doses of inoculant. *Acta Agronómica, 67*(2), 297–302. https://doi.org/10.15446/acag.v67n2.56375

Pedrozo, A., Oliveira, N. J. G. de, & Alberton, O. (2018). Biological nitrogen fixation and agronomic features of soybean (Glycine max (L.) Merr.) crop under different doses of inoculant. *Acta Agronómica*, *67*(2), 297–302. https://doi.org/10.15446/acag.v67n2.56375

Purcell, L. C., Salmeron, M., & Ashlock, L. (2014). *Soybean Growth and Development (2234)* http://www.midsouthsoybeans.com/2234_Final_Report.pdf

Rechiatu, A., Nana, E.-M., & Clement, A. R. (2015). Response of Soybean (Glycine max L.) to Rhizobia Inoculation and Molybdenum Application in the Northern Savannah Zones of Ghana. *Journal of Plant Sciences*, *3*(2), 64. https://doi.org/10.11648/j.jps.20150302.14

S, L., D K, A., S, Y., & C, A. (2014). Response of soybean (glycine max) to rhizobial inoculation and phosphorus application. *Journal of Experimental Biology and Agricultural Sciences*, *2(1)*, 72–77. http://www.jebas.org/wp-content/uploads/2014/09/Lamptey-et-al-JEBAS.pdf

Santos, M. S., Nogueira, M. A., & Hungria, M. (2019). Microbial inoculants: Reviewing the past, discussing the present and previewing an outstanding future for the use of beneficial bacteria in agriculture. *AMB Express*, *9*(1), 205. https://doi.org/10.1186/s13568-019-0932-0

Sayyed, R. Z., Reddy, M. S., & Antonius, S. (2019). *Plant Growth Promoting Rhizobacteria (PGPR): Prospects for Sustainable Agriculture*. Springer, UK.

Siamabele, B. (2019). Soya Beans Production in Zambia: Opportunities and Challenges. *American Journal of Agricultural and Biological Sciences, 14*(1), 55-60 http://dx.doi.org/10.3844/ajabssp.2019.55.60

Solomon, T., Pant, L. M., & Angaw, T. (2012). Effects of Inoculation by Bradyrhizobium japonicum Strains on Nodulation, Nitrogen Fixation, and Yield of Soybean (Glycine max L. Merill) Varieties on Nitisols of Bako, Western Ethiopia. *International Scholarly Research Notices Journal*, *8*(12), 611-620. https://doi.org/10.5402/2012/261475

Staton, M. Extension, M, S, U. (2014). *Phosphorus and potassium fertilizer recommendations for high-yielding, profitable soybeans*. https://www.canr.msu.edu/news/phosphorus_and_potassium_fertilizer_recommendations_for_high_yielding_profitable soybeans

Sylvain, N. M. (2020). *(PDF) The effect of rhizobium inoculation with nitrogen fertilizer on growth and yield of soybeans (Glycine max L.) International Journal of Biosciences | IJB* |. ResearchGate. http://dx.doi.org/10.12692/ijb/10.3.163-172

Tahir, M., Abbasi, K., Rahim, N., Khaliq, A., Kazmi, M., Jammu, A., & Pakistan, K. (2009). Effect of Rhizobium inoculation and NP fertilization on growth, yield and nodulation of soybean(Glycine max L.) in the sub-humid hilly region of Rawalakot Azad. *African Journal of Biotechnology*, *8*, 6191–6200. https://doi.org/10.5897/AJB09.1039

Ulzen, J., Abaidoo, R. C., Mensah, N. E., Masso, C., & AbdelGadir, A. H. (2016a). Bradyrhizobium Inoculants Enhance Grain Yields of Soybean and Cowpea in Northern Ghana. *Frontiers in Plant Science*, *7*(42), 1021-1023. https://doi.org/10.3389/fpls.2016.01770

Ulzen, J., Abaidoo, R. C., Mensah, N. E., Masso, C., & AbdelGadir, A. H. (2016b). Bradyrhizobium Inoculants Enhance Grain Yields of Soybean and Cowpea in Northern Ghana. *Frontiers in Plant Science*, *7*(45), 1193-1233. https://doi.org/10.3389/fpls.2016.01770

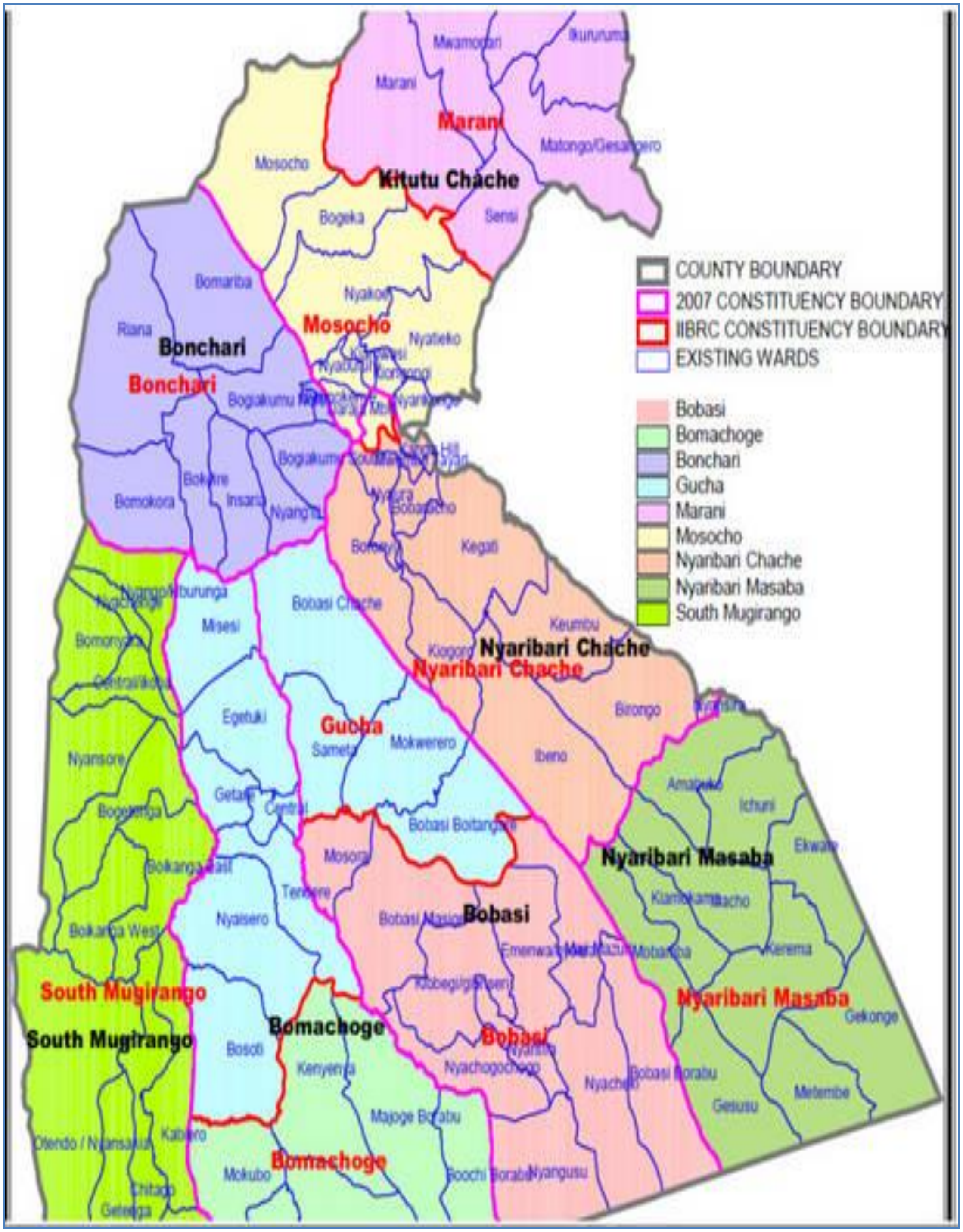
Ulzen, J., Abaidoo, R. C., Mensah, N. E., Masso, C., & AbdelGadir, A. H. (2016c). Bradyrhizobium Inoculants Enhance Grain Yields of Soybean and Cowpea in Northern Ghana. *Frontiers in Plant Science*, *7*(7), 1770-1777 https://doi.org/10.3389/fpls.2016.01770

Yeboah, S. (2014). Response of Soybean (Glycine Max) To Rhizobial Inoculation And Phosphorus Application. *Journal of Experimental Biology and Agricultural Sciences*, *2*(1), 72–77. http://www.jebas.org/wp-content/uploads/2014/09/Lamptey-et-al-JEBAS.pdf

Zhou, H., Yao, X., Zhao, Q., Zhang, W., Zhang, B., & Xie, F. (2019). Rapid Effect of Nitrogen Supply for Soybean at the Beginning Flowering Stage on Biomass and Sucrose Metabolism. *Scientific Reports*, *9*(1), 1–13. https://doi.org/10.1038/s41598-019-52043-6

APPENDICES

APPENDIX 1 ***Kisii County Map***



APPENDIX 11: SOIL TEST REPORTS.

a) SOIL ANALYSIS RESULTS BEFORE PLANTING.

	Soil Analytical Data	
Field or plot	Doris Omwocha	
Lab. No/2018	75/18	
Soil depth /cm	Top soil	
Fertility results	Value	Class
Soil Ph	5.5	moderately acidic
Elect. Cond. µs/cm	0.06	Moderate
Org. Carbon %	2.4	Adequate
Phosphorus ppm	20	Moderate
Nitrogen (%)	0.12	Low
Manganese me %	1.5	Adequate
Potassium me%	40	Very low

b) SOIL TEST REPORT FROM KALRO FCRC KISII

	Soil Analytical Data					
Field						
Plot	TRM 1 (BLOCK 3 WITHOUT DAP)		TRM 2 (CONTROL WITH DAP)		TRM 3 (1.5 COMMO)	
Lab. No/2019	18/19		19/19		20/19	
Soil depth /cm	Top soil		Top soil		Top soil	
Fertility results	Value	Class	Value	Class	Value	Class
Soil Ph	5.3	moderately acid	4.8	strongly acid	4.8	strongly acid
Elect. Cond. µs/cm	0.03	Moderate	0.02	Moderate	0.02	Moderate
Org. Carbon %	2.4	Moderate	1.9	Moderate	2.0	Moderate
Phosphorus ppm	20	Low	18	Low	16	Low
Total Nitrogen %	0.08	Low	0.1	Low	0.04	Low
Manganese me %	1.6	Adequate	1.5	Adequate	1.5	Adequate
Potassium me%	40	Very low	45	Very low	46	Very low

Plot	TRM 7 (COMMO 1M)
Lab. No/2019	24/19

Plot	TRM 4 (Rhizi LQ)		TRM 5 (Rhizi LQ +1.5 ML)		TRM 6 (Rhizi + 1M)	
Lab. No/2019	21/19		22/19		23/19	
Soil depth /cm	Top soil		Top soil		Top soil	
Fertility results	Value	Class	Value	Class	Value	Class
Soil Ph	4.3	extremely acid	4.6	strongly acid	4.3	extremely acid
Elect. Cond. µs/cm	0.03	Moderate	0.02	Moderate	0.05	Moderate
Org. Carbon %	2.0	Moderate	2.0	Moderate	2.0	Moderate
Phosphorus ppm	19	Low	17	Low	19	Low
Total Nitrogen %	0.09	Low	0.1	Low	0.07	Low
Manganese me %	1.4	Adequate	1.6	Adequate	1.4	Adequate
Potassium me%	40	Very low	45	Very low	40	Very low

APPENDIX III ***Annual Rainfall Data (2009 to 2019)***

Month	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Jan	111.2	98.8	100.7	14.9	66.4	60.3	12.6	157	36.0	63.9	24.3
Feb	61.3	99.6	42.5	66.4	75.3	40.7	42.6	53.2	101.1	38.3	21.7
March	237.3	193.5	138.6	153.5	244.2	183.2	82.3	109	114.3	386.9	166.4
April	230.1	230.8	228.7	343.6	448.5	129.8	263.3	322.83	284.2	252.4	223.1
May	279.4	406.3	267.5	256.9	244.5	194.0	268.5	365.1	205.3	296.9	189.4
June	152.3	192.0	91.6	270.7	93.8	185.7	191.9	87.3	178.7	134.6	164.1
July	63.2	73.6	100.5	100.4	94.4	154.3	104.4	32.2	65.8	80.1	
Aug	197.2	188.2	233.6	204.6	131.4	362.4	127.6	143.4	203.2	135.2	
Sept.	201.0	251.6	227.1	238.8	240.4	224.4	298.4	192.2	215.1	84.2	
Oct.	86.2	213.3	183.0	171.7	122.6	198.2	261.2	72.1	254.5	140.4	
Nov.	170.1	108.9	360.6	301.1	207.3	149.9	302.5	142.9	127.8	142.4	
Dec.	305.5	188.5	206.8	131.6	102.2	79.8	244.2	49.2	54.8	174	
Total	2094.8	2245.1	2181.2	2254.2	2254.2	1962.7	2199.5	1726.43	1840.8	1929.3	789

APPENDIX IV: *Experimental Data*

Block	Treatment	Germination %	50% Flowering	Above ground biomass (gm)	6plants pod weight (gm)	6plants seed weight (gm	Weight of seed per plot (g)	Weight of 100 seeds	Yield per acre	Bags grain/ acre (90kgbag)	Yield kg/ha
1	CoMo1ml	82.00	84.00	2,176.00	50.00	38.00	690.00	16.00	465.290	5.20	1,151
1	CoMo1.5	88.00	86.00	3,990.00	72.00	42.00	660.00	16.00	445.060	5.00	1,100
1	Rhizilq	82.00	69.00	3,160.00	78.00	54.00	868.00	16.00	585.321	6.50	1,447
1	CoMo1/r	89.00	83.00	3,156.00	88.00	50.00	820.00	18.00	552.953	6.10	1,367
1	CoMo1.5/ r	79.00	67.00	4,122.00	52.00	50.00	814.00	18.00	548.907	6.00	1,357
1	DAP	83.00	79.00	2,658.00	65.00	44.00	750.00	15.00	505.075	5.60	1,250
1	Control	58.00	54.00	1,128.00	54.00	52.00	566.00	13.00	381.867	4.20	943
2	CoMo1	90.00	59.00	2,658.00	56.00	38.00	574.00	16.00	387.067	4.30	957
2	CoMo1.5	90.00	64.00	4,664.00	80.00	42.00	780.00	18.00	525.980	5.80	1,300
2	Rhizoliq	83.00	55.00	4,158.00	72.00	54.00	680.00	18.00	409.994	4.50	1,133
2	CoMo1/r	87.00	67.00	5,128.00	62.00	50.00	816.00	16.00	550.256	6.10	1,360
2	CoMo1.5/ r	78.00	63.00	4,138.00	58.00	50.00	848.00	18.00	471.834	6.30	1,413
2	DAP	76.00	55.00	3,160.00	76.00	44.00	670.00	16.00	451.803	5.00	1,117
2	Control	87.00	50.00	1,180.00	30.00	52.00	505.00	12.00	340.538	3.70	840
3	CoMo1	83.00	54.00	2,244.00	58.00	38.00	728.00	18.00	490.914	5.40	1200
3	CoMo1.5	88.00	54.00	1,162.00	53.00	54.00	970.00	18.00	654.103	7.20	1617
3	Rhizoliq	90.00	51.00	1,056.00	68.00	64.00	1,024.00	16.00	690.515	7.80	1707
3	CoMo1/r	84.00	50.00	4,154.00	73.00	32.00	1,117.00	18.00	753.230	8.30	1862
3	CoMo1.5/ r	82.00	69.00	1,734.00	66.00	36.00	1,026.00	20.00	691.866	7.60	1710
3	DAP	76.00	51.00	1,680.00	53.00	56.00	630.00	16.00	424.830	4.70	1,050
3	Control	54.00	44.00	1,342.00	48.00	34.00	490.00	14.00	330.423	3.60	817

4	CoMo1	83.00	46.00	3,690.00	46.00	38.00	654.00	16.00	441.014	4.90	1090
4	CoMo1.5	76.00	41.00	1,682.00	54.00	30.00	730.00	16.00	492.263	5.40	1217
4	Rhizoliq	75.00	51.00	4,818.00	65.00	34.00	950.00	16.00	640.616	7.10	1583
4	CoMo1/r	84.00	53.00	2,770.00	72.00	50.00	1,740.00	18.00	1,173.340	13.00	2900
4	CoMo1.5/r	74.00	44.00	4,244.00	62.00	34.00	504.00	18.00	364.140	4.00	840
4	DAP	74.00	41.00	1,694.00	62.00	38.00	790.00	16.00	532.723	5.90	1316
4	Control	73.00	40.00	1,418.00	52.00	40.00	540.00	14.00	364.140	4.00	900

APPENDIX V *SPSS Output*

a) Germination percentages

ANOVA: Tests Between-Subjects

Dependent Variable: germination percentage

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	1058.643[a]	7	151.235	3.071	.023
Intercept	32816.095	1	32816.095	666.268	.000
Block	71.429	1	71.429	1.450	.243
Treat	987.214	6	164.536	3.341	.019
Error	985.071	20	49.254		
Total	182526.000	28			
Corrected Total	2043.714	27			

a. R Squared = .518 (Adjusted R Squared = .349)

Post Hoc Tests: Duncan[a,b]

Treatments	N	Subset 1	2
WT	4	68.00	
DAP	4	77.25	77.25
CoMo1.5ml+Rhizob	4	78.25	78.25
Rhizob	4		82.50
CoMo1ml	4		84.50
CoMo1.5ml	4		85.50
CoMo1ml + Rhizob	4		86.00
Sig.		.065	.136

Means for groups in homogeneous subsets are displayed Based on observed means.

The error term is Mean Square (Error) = 50.310.

a. Uses Harmonic Mean Sample Size = 4.000.

b. Alpha = 0.05.

b) Flowering percentage

ANOVA: Tests of Between-Subjects Effects

Dependent Variable: flowering percentage 50%

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.
Corrected Model	3957.000[a]	9	439.667	9.433	.000
Intercept	94192.000	1	94192.000	2020.806	.000
Block	3242.000	3	1080.667	23.185	.000
Treat	715.000	6	119.167	2.557	.057
Error	839.000	18	46.611		
Total	98988.000	28			
Corrected Total	4796.000	27			

a. R Squared = .825 (Adjusted R Squared = .738)

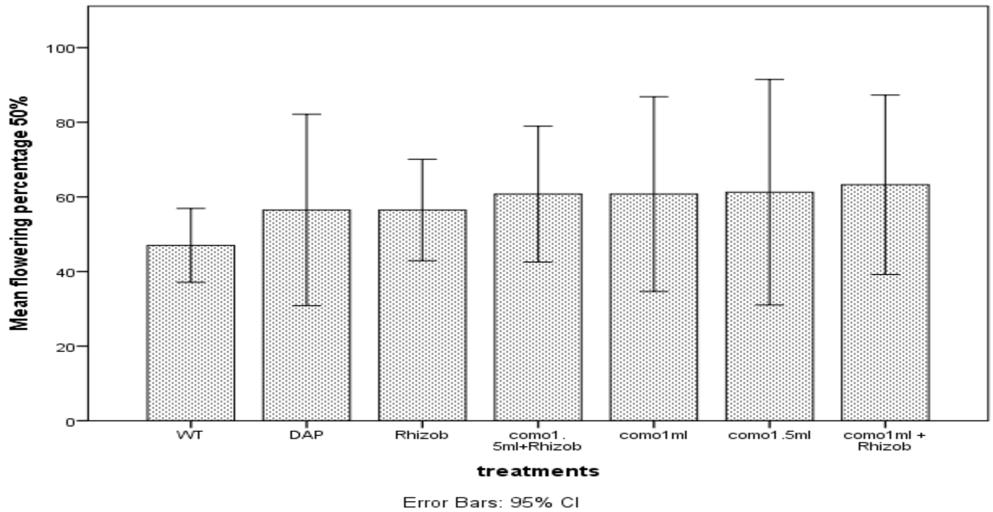
Post hoc test :Duncan[a,b]

Treatments	N	Subset 1	2
WT	4	47.00	
Rhizob	4	56.50	56.50
DAP	4	56.50	56.50
CoMo1ml	4		60.75
CoMo1.5ml+Rhizob	4		60.75
CoMo1.5ml	4		61.25
CoMo1ml + Rhizob	4		63.25
Sig.		.078	.229

Means for groups in homogeneous subsets are displayed based on observed means. The error term is Mean Square (Error) = 46.611.

a. Uses Harmonic Mean Sample Size = 4.000.

Mean flowering percent 50%



c) Weight biomass whole plot in Kgs

ANOVA: Tests of Between-Subjects Effects

Dependent Variable: weight of biomas whole plot in kg

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	18.789[a]	7	2.684	2.001	.106
Intercept	49.400	1	49.400	36.818	.000
Block	1.018	1	1.018	.758	.394
Treat	17.772	6	2.962	2.208	.085
Error	26.835	20	1.342		
Total	269.443	28			
Corrected Total	45.624	27			

a. R Squared = .412 (Adjusted R Squared = .206)

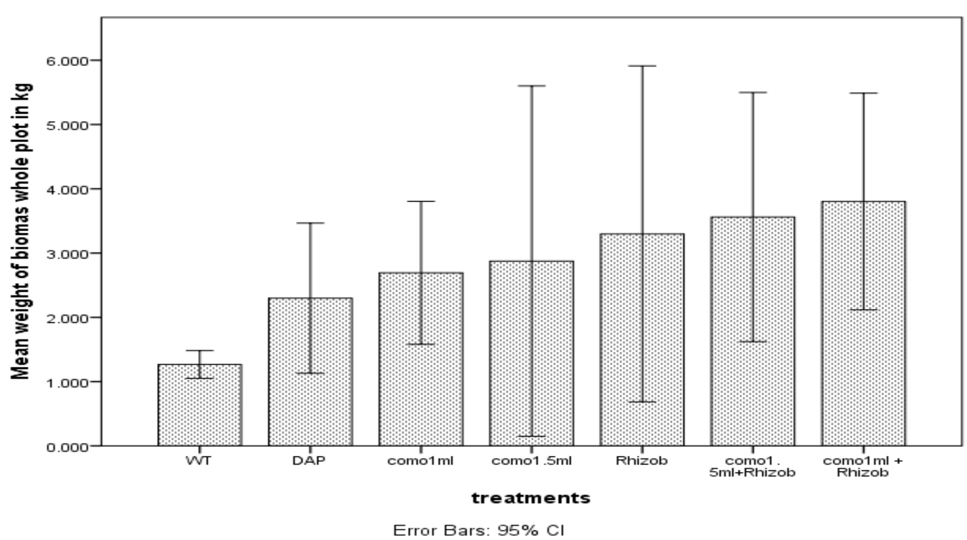
Post Hoc Test: Duncan[a,b]

Treatments	N	Subset 1	2
WT	4	1.26700	
DAP	4	2.29800	2.29800
CoMo1ml	4	2.69200	2.69200
CoMo1.5ml	4	2.87450	2.87450
Rhizob	4		3.29800
CoMo1.5ml+Rhizob	4		3.55950
CoMo1ml + Rhizob	4		3.80200
Sig.		.083	.116

Means for groups in homogeneous subsets are displayed.Based on observed means.
The error term is Mean Square (Error) = 1.326.
Uses Harmonic Mean Sample Size = 4.000.

a. Alpha = 0.05.

Mean weight biomass



d) Weight of 6 plants pods

ANOVA: Tests of Between-Subjects Effects

Dependent Variable: weight of 6 plants pods

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	2477.636[a]	7	353.948	4.319	.005
Intercept	20993.357	1	20993.357	256.166	.000
Block	167.207	1	167.207	2.040	.169
Treat	2310.429	6	385.071	4.699	.004
Error	1639.043	20	81.952		
Total	110389.000	28			
Corrected Total	4116.679	27			

a. R Squared = .602 (Adjusted R Squared = .463)

Post hoc Test: Duncan[a,b]

		Subset		
Treatments	N	1	2	3
WT	4	46.00		
CoMo1ml	4	52.50	52.50	
CoMo1.5ml+Rhizob	4	59.50	59.50	59.50
DAP	4		64.00	64.00
CoMo1.5ml	4		64.75	64.75
Rhizob	4			70.75
CoMo1ml + Rhizob	4			73.75
Sig.		.064	.100	.063

Means for groups in homogeneous subsets are displayed based on observed means.
The error term is Mean Square (Error) = 86.012.
a. Uses Harmonic Mean Sample Size = 4.000.
b. Alpha = 0.05

e) 100g seed weight

ANOVA: Tests of Between-Subjects Effects

Dependent Variable: weight of 100g seeds

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.
Corrected Model	70.500[a]	9	7.833	9.821	.000
Intercept	7557.143	1	7557.143	9474.627	.000
Block	5.143	3	1.714	2.149	.130
Treat	65.357	6	10.893	13.657	.000
Error	14.357	18	.798		
Total	7642.000	28			
Corrected Total	84.857	27			

a. R Squared = .831 (Adjusted R Squared = .746)

Post hoc Test: Duncan[a,b]

Treatments	N	Subset 1	2	3	4
WT	4	13.25			
DAP	4		15.75		
CoMo1ml	4		16.50	16.50	
Rhizob	4		16.50	16.50	
CoMo1.5ml	4		17.00	17.00	
CoMo1ml + Rhizob	4			17.50	17.50
CoMo1.5ml+Rhizob	4				18.50
Sig.		1.000	.084	.162	.131

Means for groups in homogeneous subsets are displayed based on observed means.
The error term is Mean Square (Error) = .798.

a. Uses Harmonic Mean Sample Size = 4.000.
b. Alpha = 0.05.

f) Grain yields per kg /acre

ANOVA: Tests of Between-Subjects Effects

Dependent Variable: yields kg acre

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	238148.102[a]	7	34021.157	3.908	.008
Intercept	1005389.745	1	1005389.745	115.503	.000
Block	11515.236	1	11515.236	1.323	.264
Treat	226632.867	6	37772.144	4.339	.006
Error	174088.265	20	8704.413		
Total	7680826.545	28			
Corrected Total	412236.367	27			

a. R Squared = .578 (Adjusted R Squared = .430)

Post hoc Test: Duncan[a,b]

Treatments	N	Subset 1	2	3
WT	4	354.24200		
CoMo1ml	4	446.07125	446.07125	
DAP	4	478.60775	478.60775	
CoMo1.5ml+Rhizob	4		519.18675	519.18675
CoMo1.5ml	4		529.35150	529.35150
Rhizob	4		581.61150	581.61150
CoMo1ml + Rhizob	4			657.44475
Sig.		.090	.080	.069

Means for groups in homogeneous subsets are displayed. Based on observed means. The error term is Mean Square (Error) = 8838.262.

a. Uses Harmonic Mean Sample Size = 4.000.

g) ANOVA on the effect of inoculants on yields kg ha

Dependent variable: yield kg ha

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.
Treat	2363076.929	6	393846.155	3.470	.015
Error	2383480.500	20	113499.071		
Total	4746557.429	27			

a. R Squared = .498 (Adjusted R Squared = .354)

b. ANOVA showed a significant difference among the treatment's yield per ha P (0.015>0.05). Post hoc test is shown in the table 4.12

DMRT for grain yield in kilograms per ha

Treatments	Sub set
WT	875.0000a
CoMo1ml	1099.5000ab
DAP	1183.2500ab
CoMo1.5ml+Rhizob	1308.5000ab
CoMo1.5ml	1308.5000ab
Rhizob	1467.5000bc
CoMo1ml + Rhizob	1872.2500c
Sig.	.104

c. Means difference significant at the .05 level

h) Number of Branches at harvest

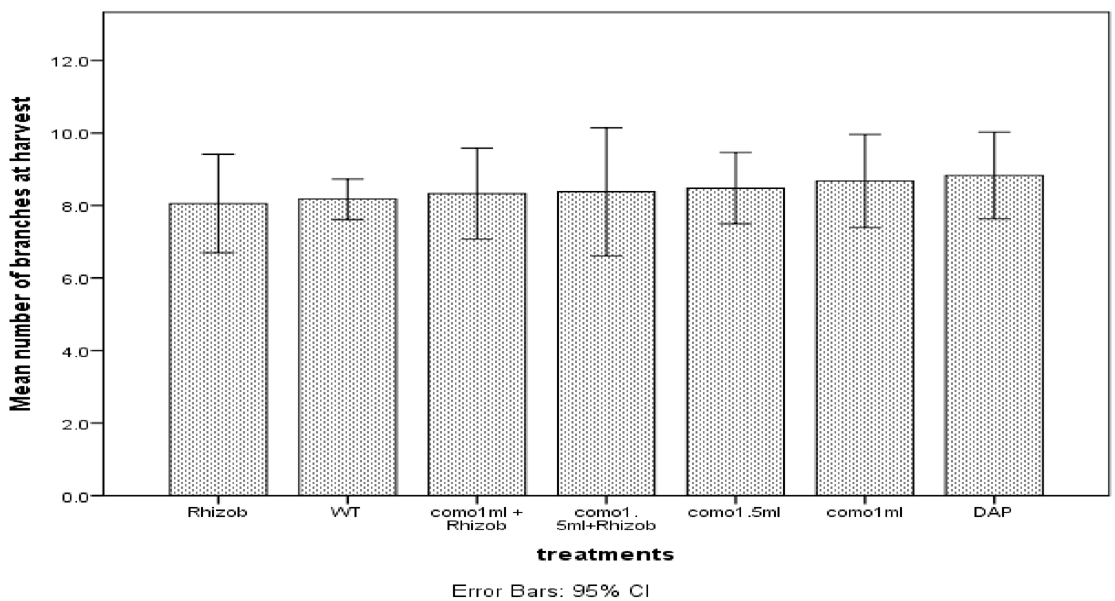
Tests of Between-Subjects Effects

Dependent Variable: number of branches at harvest

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	1.759[a]	6	.293	.478	.817
Intercept	1982.406	1	1982.406	3228.423	.000
Treat	1.759	6	.293	.478	.817
Error	12.895	21	.614		
Total	1997.060	28			
Corrected Total	14.654	27			

a. R Squared = .120 (Adjusted R Squared = -.131)

Mean number of branches at harvest



i) Height of plants at harvest

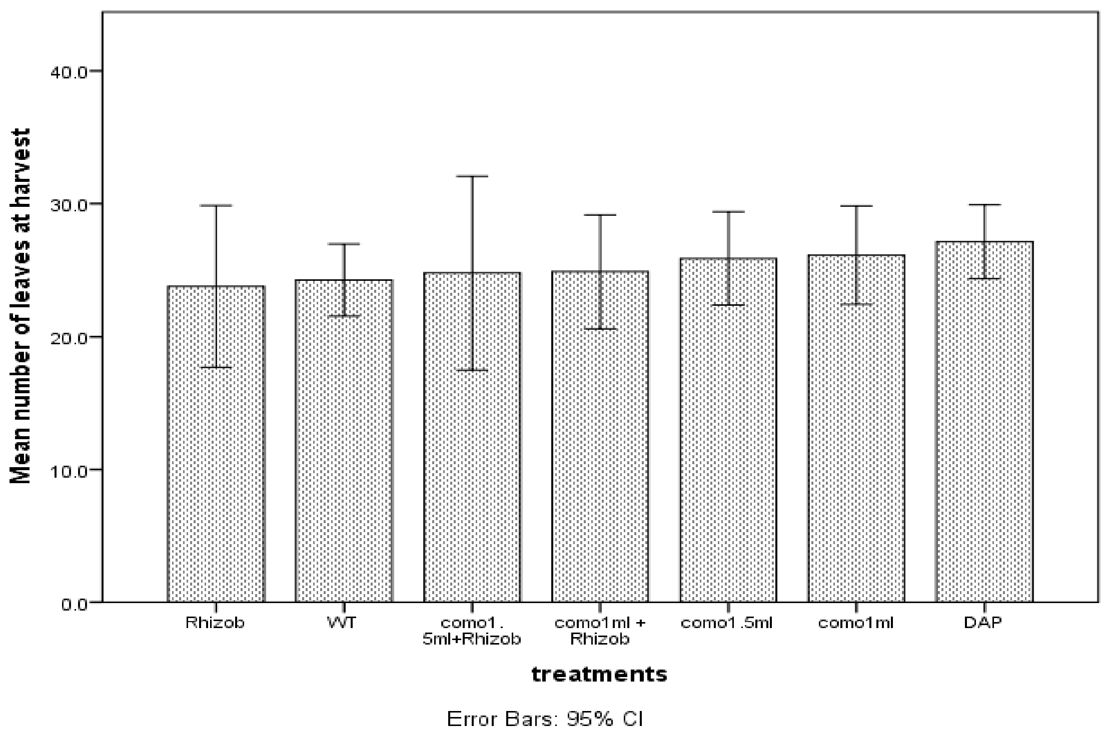
ANOVA Tests of Between-Subjects Effects

Dependent Variable: height of plants at harvest

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	198.214[a]	6	33.036	5.617	.001
Intercept	41966.286	1	41966.286	7135.968	.000
Treat	198.214	6	33.036	5.617	.001
Error	123.500	21	5.881		
Total	42288.000	28			
Corrected Total	321.714	27			

a. R Squared = .616 (Adjusted R Squared = .506)

Mean number of leaves



Post hoc test: Duncan[a,b]

Treatments	N	Subset 1	2	3
WT	4	33.00		
CoMo1.5ml+Rhizob	4		38.00	
CoMo1ml+ Rhizob	4		38.75	38.75
Rhizob	4		39.00	39.00
DAP	4		39.25	39.25
CoMo1.5ml	4		41.00	41.00
CoMo1ml	4			42.00
Sig.		1.000	.130	.102

Means for groups in homogeneous subsets are displayed.
Based on observed means.
The error term is Mean Square (Error) = 5.881.

a. Uses Harmonic Mean Sample Size = 4.000.

b. Alpha = 0.05.

j) Weight of seed whole plot

ANOVA: Tests of Between-Subjects Effects

Dependent Variable: Weight of seed whole plot

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	488114.529[a]	7	69730.647	3.958	.007
Intercept	2381428.595	1	2381428.595	135.184	.000
Block	10841.600	1	10841.600	.615	.442
Treat	477272.929	6	79545.488	4.515	.005
Error	352323.900	20	17616.195		
Total	16943394.000	28			
Corrected Total	840438.429	27			

a. R Squared = .581 (Adjusted R Squared = .434)

j) Weight of 6plants biomass

Tests of Between-Subjects Effects

Dependent Variable: weight of 6plants biomass

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	33212.257[a]	7	4744.608	2.871	.030
Intercept	65609.524	1	65609.524	39.696	.000
Block	17249.400	1	17249.400	10.437	.004
Treat	15962.857	6	2660.476	1.610	.196
Error	33055.600	20	1652.780		
Total	914692.000	28			
Corrected Total	66267.857	27			

a. R Squared = .501 (Adjusted R Squared = .327)

APPENDIX VI *Treatment Product Description*

i. Wuxal Extra COMO 15 is one product formulation, not two (i.e. Cobalt Molybdenum)

ii. BNF (Biological Nitrogen Fixation) labelled information for the commercial product, as Rhizoliq Top (Soya beans)

iii. DAP - Di-ammonium phosphate fertilizer (18:26:46

iv. Control – without any treatment

v. Wuxal Extra COMO 15 alone at 1 ml/kg

vi. DAP – Normal dosage DAP application

vii. Wuxal Extra COMO 15 at 1.5 mls/kg of seed

viii. RizoliqTop (Soya)) 3 mls/kg

ix. Rizoliq Top (Soya) 3mls /kg + Wuxal Extra COMO 15 @ 1.5 mls/kg

x. Rizoliq Top (Soya) 3mls/kg + Wuxal Extra COMO 15 @ 1mls/kg

APPENDIX VII : ***Pictorials.***

a) **Planting soya seed on the trial plots at Kisii ATC.**

b) **Planting soya bean at the trial plots for research at Kisii ATC**

c) **The Soya beans random complete block research plots at Kisii ATC**.

d) Harvesting the Soya beans at Kisii ATC.

APPENDIX VIII: *NACOSTI Permit.*

REPUBLIC OF KENYA

NATIONAL COMMISSION FOR SCIENCE,TECHNOLOGY & INNOVATION

Ref No: **324937**

Date of Issue: **20/January/2020**

RESEARCH LICENSE

This is to Certify that Ms.. DORICE OMWOCHA of Kenya Methodist University, has been licensed to conduct research in Kisii on the topic: THE EFFECTS OF FERTILIZERS MOLYBDENUM, COBALT AND RHIZOBIUM ON SOYA BEANS (Glycine Max) GROWTH AND YIELDS for the period ending : 20/January/2021.

License No: **NACOSTI/P/20/3273**

324937

Applicant Identification Number

Director General
NATIONAL COMMISSION FOR SCIENCE,TECHNOLOGY & INNOVATION

Verification QR Code

NOTE: This is a computer generated License. To verify the authenticity of this document, Scan the QR Code using QR scanner application.

APPENDIX IX: ***Publication Certificate***

Vol. - 6 | No. - 7 | July, 2020

30-Jul-2020

Article ID: 1366

CERTIFICATE OF PUBLICATION

is hereby awarded to

Peter K. Ndungu, Makobu Kimani, John Mokua Mose

for publication of article entitled

Influence of Caregiver and Peer Support in Adherence to Antiretroviral Therapy amongst HIV Positive Adolescents Attending Murang'a County Hospital.

in double blind peer reviewed and open access

International Journal For Research In Health Sciences And Nursing (ISSN: 2208-2670)

Green Publication

Virender Singh

Chairman, Board of Trustees

GREEN PUBLICATION

https://gnpublication.org

GREEN PUBLICATION

APPENDIX X: *Published Article*

GREEN PUBLICATION International Journal For Research In Agricultural And Food Science ISSN: 2208-2719

Effect of Cobalt, Molybdenum and Rhizobium on Yield of Soya Beans in Kisii County, Kenya.

Ombuna Dorice[1] , Mworia Mugambi[2], Muchiri John[3]

[123] Kenya Methodist University.

Department of Agriculture and Rural Development

Email: dorisombuna1@gmail.com, mworia. mugambi @kemu.ac.ke, john.muchiri @kemu.ac.ke

Correspondence: Dorice Omwocha,

: Email: dorisombuna1@gmail.com

Abstract.

Introduction: Soybean is a leading source of protein and oil used for human consumption and livestock feed, also considered a valuable crop globally. The leading producers worldwide are United States of America, Brazil and China that produce as high as 89.9 Million tonnes annually. In Kenya, the beans are mainly grown in the western and central regions of Kenya, and the average yield is 363 $kgha^{-1}$. This is low compared to the other countries, the poor yield in Kisii County is associated to low soil fertility, poor agronomic practices and acidified soil. Additionally, insufficient nitrogen and phosphorus in soil, use of unimproved seed varieties and poor management practices are causes. **Objectives**: The study aimed at evaluating the effects of molybdenum, cobalt and rhizobium inoculants on yield of soya beans in Kisii County. **Research methodology**: A randomised complete block design experiment was carried out at Kisii Agricultural Training Centre. Seeds were coated with ttreatments that included: Control (WT), DAP, Rhizoliq Top Soya 3m/kg, Wuxal Extra COMO1.5 at 1m/kg of seed, Wuxal Extra COMO 1.5 at 1.5 mls/kg of seed, (Wuxal Extra COMO 1.5 at 1.5 mls/kg / Rhilizic top 3mls) and (Waxul Extra15 COMO1m/Rhizoliq top 3ml/kg) of soya seed. Parameters collected were manipulated using SPSS Version 24.0, and tested using ANOVA (95% CI). Statistically significant results were further subjected to DMRT post hoc test. **Results:** Soil analysis showed moderately acidic (pH 5.5) soil low nitrogen (0.12%), moderate Phosphorus (20ppm) and low potassium levels (40%). The highest effect on six plants pod weight was shown by COMO1ml+ Rhizobium treatment. The treatments were statistically significant ($p=0.004$) and COMO1ml+Rhizob was highest on DMRT. Highest effect on 100 seeds weight was also seen with COMO1.5ml+Rhizob and p value (<0.001).DMRT showed como1.5 + Rhizob to be the highest. Further, COMO1ml+Rhizob indicated the highest effect on yield Kg per ha, ($p=0.006$). Weight of seeds of the plot was shown to be influenced highly by COMO1ml+Rhizob with ($p=0.005$). COMO1ml+Rhizob had the highest mean on DMRT. **Conclusion:** Use of inoculant in combination in improving low yield (COMO+Rhizob) at different graded levels is recommended. Research to evaluate the effects of nitrogen and phosphorus levels on soya bean production in Kisii is highly recommended.

Key words: *Agronomic, Combination, Nitrogen, Phosphorus, Fixation, Production, Treatments, Soil.*