PERFORMANCE EVALUATION OF MUNG BEAN (*Vigna radiata(L.)* Wilczek) VARIETIES UNDER VARIABLE PHOSPHOROUS FERTILIZER RATES AT ALAGE, CENTRAL RIFT VALLEY OF ETHIOPIA

M.Sc. THESIS

HABTAM TILAHUN ASRATIE

HAWASSA UNIVERSITY, HAWASSA, ETHIOPIA

JULY,2020

PERFORMANCE EVALUATION OF MUNG BEAN (*Vigna radiata(L.)* Wilczek) VARIETIES UNDER VARIABLE PHOSPHOROUS FERTILIZER RATES AT ALAGE, CENTRAL RIFT VALLEY OF ETHIOPIA

HABTAM TILAHUN ASRATIE

MAJOR ADVISOR: WALELIGN WORKU (Prof,PhD)

CO- ADVISOR: DEMELASH KEFALE (PhD)

A THESIS SUBMITTED TO THE SCHOOL OF PLANT AND HORTICULTURAL SCIENCES, COLLEGE OF AGRICULTURE, SCHOOL OF GRADUATE STUDIES, HAWASSA UNIVERSITY, HAWASSA, ETHIOPIA

IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE IN PLANT SCIENCES (SPECIALIZATION: AGRONOMY)

HAWASSA UNIVERSITY, HAWASSA, ETHIOPIA

JULY, 2020

SCHOOL OF GRADUATE STUDIES

HAWASSA UNIVERSITY

ADVISORS' APPROVAL SHEET -I

(Submission sheet-1)

This is to certify that the thesis entitled **"Performance Evaluation of Mung Bean (*Vigna Radiata(L.)* Wilczek) Varieties Under Variable Phosphorous Fertilizer Rates at Alage, Central Rift Valley of Ethiopia"**, submitted in partial fulfillment of the requirements for the degree of Master's science with specialization in Agronomy, the Graduate Program of the School of Plant and Horticultural Sciences, Hawassa University, College of Agriculture and has been carried out by **Habtam Tilahun**, under our supervision.Therefore, we recommend that the student has fulfilled the requirements and hence hereby can submit the thesis to the School.

Approved by Advisors:

WALELIGN WORKU (Professor,PhD) ______________ _____________

Name of major advisor Signature Date

DEMELASH KEFALE (PhD) _______________ _____________

Name of co-advisor Signature Date

SCHOOL OF GRADUATE STUDIES

HAWASSA UNIVERSITY

EXAMINERS' APPROVALSHEET-I

(Submission sheet-2)

We, undersigned, members of the Board of Examiners of the final open defense by **Habtam Tilahun** have read and evaluated her thesis entitled **"Performance Evaluation of Mung Bean (*Vigna Radiata(L.)* Wilczek) Varieties Under Variable Phosphorous Fertilizer Rates at Alage, Central Rift Valley of Ethiopia"** and examined the candidate.This is therefore to certify that the thesis has been accepted in partial fulfillment of the requirements for the degree of master of sciences.

______________________	______________	____________
Name of Chairpersons	Signature	Date
______________________	______________	____________
Name of Major Advisor	Signature	Date
______________________	______________	____________
Name of Co-Advisor	Signature	Date
______________________	______________	____________
Name of Internal Examiner	Signature	Date
______________________	______________	____________
Name of External Examiner	Signature	Date
______________________	______________	____________
SGS Approval	Signature	Date

Final approval and acceptance of the thesis is contingent upon the submission of the final copy of the thesis to the School of Graduate Studies (SGS) through the School Graduate Committee (SGC) of the candidate's School.

ACKNOWLEDGMENTS

Above all, I would like to give thanks and glorify the Almighty God, who gave me life and health that I required to complete this study and fulfill all aspirations of my life.

It is true that this paper was made possible through the combined efforts of a great number of people whom I would like to heartfully thank a lot. I would like to express my sincere and deepest appreciation to my major advisor, Prof. Walelign Worku and co-advisor Dr.Demelash Kefale for their consistent guidance, valuable comments and constructive criticisms throughout the research work up to the final thesis write up. My very special thanks and appreciation goes to Alage Agricultural Technical Vocational Education and Training College for allowing me to use experimental field for my research work and car during the research field visit of my advisor. I would like also to express my heartfelt thanks to all members of staff in the Department of Plant Sciences, secretary, store keeper and plant science students in Alage ATVET College for their support in my studies. Any special words of gratitude and thanks cannot express my indebtedness to my father Tilahun Asratie, my mother Tibka Demssie, whose crucial decision to invest part of their major resource in my education had laid a base for me to reach where I am today.

I would like also to express my heartfelt thanks to my Husband Yetsedaw Kassa and my sisters Yidenek Tilahun, Melkam Abitew, Hana Asratie and Haymanot Kassa for their support in my research work. Last but not least of my heartfelt appreciations are extended to Mrs. Belete Tsegaye for constant encouragement and support throughout my study period.

DEDICATION

This thesis is dedicated to my mother Tibka Demssie and my sister Yidenek Tlahun for their contribution to the success in my life.

STATEMENT OF THE AUTHOR

By my signature below, I declare and affirm that this thesis is a result of my own work. I have followed all ethical and technical principles of scholarship in the preparation, data collection, data analysis, and compilation of this thesis. Any scholarly matter that is included in the thesis has been given recognition through citation and all sources of materials used for this thesis have been duly acknowledged. This thesis has been submitted in partial fulfillment of the requirements for an advanced M. Sc. degree at Hawassa University and is deposited at the university library to be made available to borrowers under rules of the library. I solemnly declare that this thesis is not submitted to any other institution anywhere for the award of any academic degree, diploma, or certificate.

Brief quotations from this thesis are allowable without special permission provided that accurate acknowledgement of source is made. Requests for permission for extended quotation from or reproduction of this manuscript in whole or in part may be granted by the School head of Plant and Horticultural Sciences or the Dean of the School of Graduate Studies when in his or her judgment the proposed use of the material is in the interests of scholarship. In all other instances, however, permission must be obtained from the author.

Name: Habtam Tilahun Asratie

Signature ____________

Date__________________

School of Plant and Horticultural Sciences

LIST OF ABBREVIATIONS AND ACRONYMS

AARC:	Awassa Agriculture Research Center
AGY:	Adjusted Grain Yield
CSA:	Central Statistics Authority
CV:	Coefficient of Variations
DAFF:	Department of Agriculture, Forestry, and Fisheries
ds m^{-1} :	Desi Siemens Per Meter
ECX:	Ethiopian Commodity Exchange
EIAR:	Ethiopian Institute of Agriculture Research
ETB:	Ethiopian birr
EPP:	Ethiopian Pulses Profile
GFB:	Gross field benefit
MARC:	Melkasa Agricultural Research Center
MoANR;	Ministry of agriculture and natural resources
NFB:	Net Field Benefit
SAS:	Statistical Analysis Software
TVC:	Total Variable Cost
UGY:	Unadjusted Grain Yield
USD:	United States Dollar
WWDSE:	Water Works Design and Supervision Enterprise

TABLE OF CONTENTS

Titles **Page**

LIST OF TABLES

Tables **Page**

LIST OF FIGURES

Figures **Page**

LIST OF TABLES AND FIGURES IN THE APPENDICES

Appendices **Page**

Performance Evaluation of Mung Bean (*Vigna Radiata(L.)* Wilczek) Varieties Under Variable Phosphorous Fertilizer Rates at Alage, Central Rift Valley of Ethiopia

Habtam Tilahun Asratie(B.Sc), Debre Markos University
Major Advisor:- Walelign Worku (Prof,PhD), Hawassa University
Co- Advisor:- Demelash Kefale (PhD), Hawassa University

ABSTRACT

Mung bean is an important pulse crop in Ethiopia. However, lack of adapted high yielding varieties and poor soil fertility, especially low levels of nitrogen and phosphorus, have been demonstrated to be important constraints for the production of the crop. Field experiment was conducted during the 2019 belg season to determine the Performance Evaluation of Mung Bean (Vigna Radiata(L.) Wilczek) Varieties Under Variable Phosphorous Fertilizer Rates at Alage Agricultural Technical and Vocational Education Training college Experimental field. The treatments consisted of factorial combinations of four mung bean varieties (Boreda-1, N26, NVL-1 and shoa robit local) and four phosphorus fertilizer rates (0, 23, 46 and 69 kg P_2O_5 ha^{-1}) laid out in Randomized Complete Block Design with four replications. Data were collected on plant height , number of nodules $plant^{-1}$, nodules dry weight $plant^{-1}$, root dry weight $plant^{-1}$, shoot dry weight $plant^{-1}$, number of branches $plant^{-1}$,number of pods $plant^{-1}$, number of seeds pod^{-1}, hundred seeds weight, grain yield, harvest index, biological yield, days to flowering and maturity. The variety Boreda-1 showed the best performance in number of pods $plant^{-1}$, number of seeds pod^{-1} ,and grain yield whereas NVL-1 gave the lowest performance.Variety Boreda-1 also gave the highest gross benefit of 47624.22 ETB and the highest net benefit of 46749.22 ETB. But the lowest gross return and net return were obtained from variety NVL-1 ,with 40044.38 ETB and 39169.38 ETB, respectively. The increasing rates of phosphorous fertilizer showed substantial improvement in nodules dry weight $plant^{-1}$, shoot dry weight $plant^{-1}$, plant height, grain yield, and biological yield up to fertilizer rates of 46 kg P_2O_5 ha^{-1}. Application of 46 kg P_2O_5 ha^{-1} recorded the highest gross income of 47053.13 ETB and net return of 45003.13 ETB and the lowest values were recorded from the control; which were 40280.63 *ETB and* 40280.63 *ETB in that order. From the study,the interaction of variety Boreda-1 with phosphorous fertilizer rates of 46 Kg P_2O_5 ha^{-1} recorded highest gross income of 50321.25 ETB and net return of 47396.25 ETB .While, the lowest was recorded from the interaction of variety NVL-1 with phosphorous fertilizer rates of 0 Kg P_2O_5 ha^{-1} with a gross income of 36303.75ETB and net return of 35428.75 ETB. Accordingly,variety Boreda-1 and application of 46 kg P_2O_5 ha^{-1},can be used to improve productivity of mung bean in the study area.*

Key words: grain yield , growth parameters, variety ,yield components

1. INTRODUCTION

Legumes have been used for many years by Ethiopian farmers in crop rotation and intercropping to maintain soil fertility. Legumes also hold a vital importance in improving food and nutrition security, generation of income, providing livestock feed, soil erosion control and water conservation, and as a source of fuel (Erana,2020). Mung bean (*Vigna radiata (L.)* Wilczek) belongs to the family leguminoseae and sub-family papilionaceae. It is a tropical, warm season legume crop adapted to a variety of soils (Karim *et al*., 2014). Mung bean can be easily grown in newly reclaimed sandy soils and can be irrigated with saltwate (Mohamed, 2005). The optimum temperature requirements for this crop ranges from 18-24^{o}C (Karim *et al*., 2014). Mung beans are a warm season crop requiring 90-120 days of frost free conditions from planting to maturity (MoANR, 2016). Mung beans are annual legume crops grown for their grain. Most mung bean grains are either green or yellow while some are black. It is cultivated in several countries in Asia, Africa, and America (Karanja, 2016).

The world demand for Mung bean is increasing because of its significance to human nutrition as a source of proteins, complex carbohydrates, vitamins, and minerals. In Ethiopia mungbean has considerable importance in economical for income generation, as food, fodder etc.(Tarikua, 2017). Mung bean sprouts are high in protein (21% -28%), calcium, phosphorus, and certain vitamins. Because they are easily digested they replace scarce animal protein in human diets in tropical areas of the world (MoANR, 2016). Eating mung beans helps to reduce the cholesterol level in the body and helps in regulating the blood pressures in a healthy manner and in that process it maintains the arteries and veins in good condition (Minh, 2014). `

Mung bean plays key role in economic value, nutrition value and it adds nitrogen fertilizer to soil through bacterial symbiosis. Although mung bean is not indigenous to Ethiopia, its cultivation exists at some low land regions. However, mung bean genotypes used by Ethiopian farmers are very few and still there is no improved cultivar which can tolerate to different geographical location, resistant to diseases and insects, produce high yield and nutrition quality (Itefa, 2016). Mung bean will contribute towards soil fertility through nitrogen fixation; through deep root system that will utilize and recycle nutrients at depth; through residues that increase organic matter and improve soil structure; and through protection of the soil from erosion (Asim, 2006).

Farmers prefer Mung bean because of crop characters like, ability to resist harsh conditions (drought stress, less soil fertility), and early maturing crop. The crop is well adapted under warm,and drought ecological areas of Ethiopia (Tensay, 2015). There is a need to identify better-yielding and well adapted cultivars, to develop appropriate agronomic packages and popularize the crop in order to realize the crop's potential,and varieties could give relatively better yield (Fanuel and Walelign, 2013). About four improved varieties were released by various research centers. Varieties released by Melkassa Agricultural Research Institute were (NVL-1,and Rasa (N-26)), while by Southern Agricultural Research Institute (MH-97-6(Boreda-1)),and by Humera Agricultural Institute(Arkebe(SML-6 68)) (MOANR,2016).

Improved technologies, high yielding varieties, and appropriate crop management practices are major techniques to enhance the productivity of mung bean. Therefore, a concerted effort by farmers, researchers, development agencies, and government are needed to ensure the opportunities for Mung bean production (Mesfin, 2017). The requirement for phosphorus is greater for healthy crop growth with efficient root system and profuse nodulation. Phosphorus plays a key role in pod filling and ultimately enhances the production (Karim *et al*., 2014). Phosphorus helps for better vegetative growth,and photosynthetic activity ascribed by larger uptake of nutrients,and water from the soil by well developed root systems and profuse nodulation which caused an increased in N supply from symbiotically fixed N in root nodules (Sipai *et al.,* 2016).

An adequate and balanced supply of essential nutrients is a cornerstone of improvements in crop productivity. Improved phosphorous use efficiency will become increasingly important in the future as farmers strive to achieve higher levels of productivity. In regions where crops are chronically malnourished, increases in soil P fertility through soil improvement and fertilizer use will underpin increases in productivity (Bovill *et al.,*2013). In areas where P has been applied in excess of the crop requirements, better use of the soil P bank and a more sustainable use of fertilizer P will be needed (Bovill *et al.,* 2013). Most of the inorganic P added to soils in fertilizers is usually adsorbed initially, but it may become absorbed by diffusive penetration of phosphate ions into soil components. It is considered that this added P is held with a continuum of bonding energies on the surfaces, or within, soil components, and this gives rise to the differing extractability of soil P and its differing availability to plants (FAO, 2008).

Khan *et al*. (2002) obtained a linear increasing trend in total biomass, straw yield, and grain yield of mung bean with increasing the rates of phosphorous fertilizer from 0 Kg P_2O_5 ha $^{-1}$ to 100 Kg P_2O_5 ha^{-1}. Since P is readily mobilized in the plant, when a deficiency occurs the P is translocated from older tissues to active meristematic tissues, resulting in foliar deficiency symptoms appearing on the older (lower) portion of the plant. Other effects of P deficiency on plant growth include delayed maturity, reduced quality of forage, fruit, vegetable, and grain crops, and decreased disease resistance (Gautam, 2017). Plant-available soil phosphorus is a term used to mean the portion of soil P that can be taken up from soil by crop roots. However, the portion of usable or plant-available P in native soils is very low. Much of the native soil P is contained in soil minerals and in soil organic matter in forms that remain unavailable to plants. The frequency of crop response to added phosphate fertilizer can be strongly influenced by environmental conditions, particularly soil temperature and moisture. Plant availability of P can be also affected by soil pH. Soil P is slightly more available in a pH range of 6.0 to 7.5. At higher pH levels (>7.5), calcium,and magnesium may react with phosphorus;creating forms that have slightly lower availability to plants (McKenzie, and Middleton, 2013).

Mungbean is not yet produced in the study area eventhogh it can be potential production area. This requires tests to identify adapted higher yielding cultivars and fertilizer recommendations. Moreover, farmers in our country generally have a wrong notion about pulses ,that being a legume crop they do not need any nutrient and usually grow on the marginal lands without applying any fertilizer. It is important to make recommendations to farmers in the study area that would help them grow mung bean crop in addition to other crops by using appropriate varieties,and optimum rates of phosphorous fertilizer. There is a need to identify the genetic yield potential of the existing improved mung bean varieties with optimum phosphorus fertilizer rates. Thus, this experiment was done to evaluate the performance of mung bean varieties under different rates of phosphorous fertilizer in the study area.

Specific objectives were:

❖ To determine the effects of varieties, and different phosphorous fertilizer rates on growth, yield and yield components of mung bean.

❖ To investigate the possible interaction effects of phosphorous fertilizer rates and varieties on the growth, yield and yield components of mung bean.

❖ To determine the economic feasibility of mung bean varieties, different phosphorous fertilizer rates, and their interactions in the study area.

2. LITERATURE REVIEW

2.1. Origin and Distribution of Mung Bean

It originated in India or in the Indo-Burmese region . Mung bean cultivation spread in early times to most other Asian countries and later to Africa, Australia and the Americas. In Uganda, mungbean production is concentrated mainly in the eastern and northern regions and is mainly cultivated at a subsistence level by smallholder farmers. The crop, however, is steadily being adopted by large-scale commercial farmers in the country targeting its growing demand, especially in the regional and international markets in Asia (Mbeyagala *et al*., 2017). Presently, mung bean is the most important grain legume in Thailand and the Philippines; it ranks second in Sri Lanka and third in India, Burma, Bangladesh,and Indonesia (Sehrawat *et al.,* 2013). The main production areas in south Africa are Limpopo and Mpumalanga, where it is produced mainly for consumption. Mung beans are not produced on a commercial scale. Several attempts at research into Mung bean production have been made in South Africa, but with no success. This is largely because of late and erratic pod maturing, which makes it difficult to determine the harvesting period. It is also low yielding and susceptible to disease (DAFF, 2010).

2.2. Description and Climatic Requirements of Mung Bean

Mung bean is in the Legume family of plants and is closely related to cowpea. It is a warm season annual, highly branched and having trifoliate leaves like the other legumes. The pale yellow flowers are borne in clusters of 12-15 near the top of the plant. Mature pods are variable in color (yellowish-brown to black); about five inches long, and contain 10 to 15 seeds. Self pollination occurs in the crop; so insect and wind are not required. Mature seed colors can be yellow, brown, mottled black or green, depending upon variety (MoANR, 2016). The seeds are free from glycosides. The seed color exhibits a wide range of variations at maturity from yellow, greenish-yellow, light-green and shiny green to dark-green, dull green, black, brown, and green mottled with black (DAFF, 2010).

Pod maturity in mung bean is not uniform because the plants flower over an extended period. This makes it difficult to decide when to harvest. Generally harvest should begin when one half to two-thirds of the pods are mature. Seeds might be between 13%-15% moisture at this time(Arain, 2012). The optimum temperature range for growth is between 27°C and 30°C. This means that the crop is usually grown during summer. Seed can be planted when the minimum temperature is above 15°C. Mung beans are responsive to daylight length. Short days result in early flowering, while long days result in late flowering depending on variety. Mung bean is considered to be heat and drought tolerant (Habte , 2018). Adequate rainfall is required from flowering to late pod filling in order to ensure good yield. Mung beans are adapted to the same climatic areas as soybean, dry bean and cowpea (MoANR, 2016). Mung bean is mainly produced in areas having a rainfall record of 600 to 1000mm; sensitive to water logging (Kidane and Bedru, 2000).

Late plantings which result in flowering during the high temperature-low moisture periods will reduce yield. High humidity and excess rainfall late in the season can result in disease problems and harvesting losses due to delayed maturity. Mung beans do best on fertile, sandy loam soils with good internal drainage and a pH range of 6.3- 7.2. Mung beans require slightly acid soil for best growth. Root growth can be restricted on heavy clays (DAFF, 2010). Mung bean requires a starter dose of 18 kg Nitrogen ha^{-1}. For supply of phosphorus 100 kg TSP ha^{-1} should be applied. Mung bean is a crop of indeterminate flowering habits,and its pods mature subsequently. The crop has a slight shattering habit so mature pods are to be harvested as soon as possible. Generally, two to three pickings are sufficient. However, if new flowers are produced triggered by rainfall at the time of harvest, two extra pickings may be required then the cumulative harvest increases by 30 percent of the normal yield (FAO, 2012).

2.3. Mung Bean Production and its Economic Importance in Ethiopia

Mung bean is an important crop in Ethiopia. However, poor soil fertility, especially low levels of nitrogen and phosphorus, has been demonstrated to be a major constraint to the production of the crop in the country (Abayneh, 2018). From a total of 12.4 million hectares of farmland in Ethiopia, the majority is used for production of cereals(9.16 million hectares); a relatively small area is seeded to pulses (1.41 million hectares) (FAO, 2010). Mung bean is originated from India and it has diversified to East, South, Southeast Asia (China), and some countries in Africa. The average yield of the crop is limited to 600-800 kg ha^{-1} due to different reasons (EPP, 2004).

Mung bean is known locally as “Masho”. It is a recent introduction in the Ethiopian pulse production and grown in few areas of the country. The volume of production is also very small,and it is concentrated mainly in North Shewa and South Wollo zones of Amhara region and in some woredas of Beneshalgul Gumuz region. The ECX mung bean contract classifies the bean in to two varieties by production areas. These are: Green mung bean Shoa and green mung bean Asossa type. Best adaptation areas for Mung bean are at 1,000-1,650 meters above sea level; with annual rainfall of 600-750mm. Its production in Ethiopia is most suited with clay loam fluvsol, clay eutric fluvisol, and pellic vertisol types of soil. It is usually sown at “Belge” rainy season between Februarys to April and “Mehere” between Julys to August when the rain starts to end (EXC, 2009).

Mung bean is a useful crop in drier areas and has a good potential for crop rotation and relay cropping with cereals using residual moisture. Small holder farmers in drier marginal environments in Ethiopia grow mung bean. As compared to other pulse crops, its production in Ethiopia is very negligible. However, for resource poor farmers in drier marginal environments it has been an important grain legume (Asrate *et al.*, 2012). There is a need to expand its production to other potential areas where moisture stress is a challenge for producing long maturing crops. Even in mung bean producing areas, its farming is based on local cultivars that are low yielder, late maturing and susceptible to disease. These varieties are challenged by current climate change. Moreover, there is huge demand for mung bean in the international market particularly in south-east Asia (Wedajo, 2015).

Mung bean productivity in Ethiopia is estimated to be on average from 1.2 to 1.5 ton ha^{-1} with a volume of production is increasing year to year. Amhara and Beneshangul Gumuz regions are the two potential production areas of green mung bean. Although green mung bean is commonly used in some other countries, it is little consumed in Ethiopia even by those who produce it. It is only produced as a cash crop to generate income by selling it to exporters. The major export destinations for Ethiopian green mung bean are: Indonesia, India, Belgium, UAE, and Singapore. Other major global players in mung bean import comprises: USA, Netherlands, UK, Canada, France, Germany, Norway, Sweden, and Malaysia (EXC, 2009).

There were many studies which deal with genetic variation and yield and yield related traits of mung bean based up on morphological determination between mung bean genotypes.But most importantly, genetic improvement of the exiting genotypes at molecular DNA level biotechnological approaches can easily identify superior genotypes which can adapt to different geographical location, resistant to diseases, and insects, produce high yield (Itefa ,2016). Despite its growing demand in the international market there is chronic supply gap in Ethiopia from the production side. However, Ethiopia's mung bean export has grown slightly from time to time (EPP, 2004).

Mung bean is a widely grown cash crop in the low land areas of North Shewa. How ever its productivity was very low due to lack of improved seed and high pest and disease infestation problems (Yehuala *et al*. ,2018). There is a need to expand its production to other potential areas where moisture stress is confront for producing long maturing crops like the raya valley in northern Ethiopia. However, the improved varieties are not yet introduced to farmers in moisture stress areas (Teame *et al*., 2017). In Ethiopia local community mostly prepared mung bean as boiled seed (NIFRO (Amharic)), split seed (KIK WET (Amharic)), seed powder (SHERO WET (Amharic)) and SHORBA (Amharic)). In terms of improving soil fertility, farmers are experienced on planting of mung bean as crop rotation system with other cereals. This crop is also one way of good income generation system for farmers even if the cultivation practice is less (Tensay, 2015).

2.4. Varietal Differences in the Growth, Yield, and Yield Related Characters of mung bean

The natural variability for yield and yield related traits is very narrow in those highly-self pollinated crops like mung bean,and further selection for improvement becomes impractical due to its complex,and delicate floral structure,and very precise micro condition which is required for pollen dehiscence, and fertilization. However, proper evaluation of the extent of genetic variation available for yield components, their heritability values, and genetic advance could be of great help for the breeders in order to choose good genotypes for improvement (Itefa *et al*., 2014). Significant differences among genotypes of mung bean were observed for yield related traits which showed that there is sufficient variability to have an effective selection (Khan *et al*., 2017).

Plant height, number of leaves plant^{-1}, days to first flowering, effective pods plant^{-1}, fertile seeds pod^{-1} ,number of infertile seeds pod^{-1}, yield and seed weight were affected due to varietal differences at different days after sowing. Generally there were significant differences in the morphological and reproductive performances of different varieties of mung bean (Hossain *et al*., 2016). Another researchers reported that there are differences in pod length, number of pods plant^{-1}, number of seeds pod^{-1}, seeds weight, and grain yield between mung bean varieties (Hossen *et al*.,2015). Dry matter accumulation differed significantly among the varieties at all stages of growth. Variety had also significant effect on number of pods plant^{-1}, length of pod and number of seeds pod^{-1} (Dwivedi *et al*.,2018). Imran *et al*.(2016) also reported that cultivars significantly affected plant height, number of pods plant^{-1}, number of seeds pod^{-1}, biological yield , seed weight ,and harvest index.

Varieties of mung bean differed significantly for plant height, dry matter plant^{-1}, number of branches plant^{-1}, number of pods branch^{-1}, length of pod, number of seeds pod^{-1}, and seed weight. Stover yield, and seed yield were also significantly affected by different varieties (Zahan *et al*., 2016). Variety influenced emergence duration, plant height, number of branches plant^{-1} , total number of days after sowing to flowering, and productivity. These results can be extremely important to the selection of genotypes with the fastest rate of growth and development for cultivation programs, in order to obtain new genotypes with short vegetation periods. The number of pods plant^{-1} represents an important yield component, and should be useful as selection criteria (Robu *et al*., 2014).

The differences among varieties for leaf area and total dry mass were significant at all growth stages. The morphological (plant height and branches number plant^{-1}), phenological (flowering duration and days to maturity), and reproductive characters (number of opened flowers plant^{-1} and reproductive efficiency) differed significantly among different cultivars. It appeared that for getting superior characters of yield components, a high yielding mung bean genotype should posses a relatively larger leaf area with superior growth parameters (Mondal *et al*., 2012). In contrast to the above researchers, Rehman *et al*. (2009) reported that different varieties not perform differently in growth, yield and yield related characters such as plant height, physiological maturity, days to flowering, days to emergence, number of pods plant^{-1}, number of grains pod^{-1}, and grain yield. Ullah *et al*. (2010) also found among the genotypes, the difference of plant height, number of pods plant^{-1}, number of seeds pod^{-1}, grain weight, nodulation, and harvest index were not significant.

2.5. Effect of Phosphorous on the Growth, Yield and Yield Related Characteristics of Mung bean

Phosphorus is very important for plant growth and yield. It is prone for fixation in the soil. The serious problem of fixation reduces p-use efficiency and enhances cost of production. P-solubilizing microorganisms are boon for this problem and confer many other benefits to plants (Gupta , and Sahu , 2017). The higher fertilizer rates up to 60 kg P ha^{-1} result in better production of crop based on optimum inputs availability, and genetic makeup (Khan *et al*., 2015). Growth parameters of mung bean, viz. plant height, number of branches plant^{-1}, number of nodules plant^{-1}, plant dry weight (g), crop growth rate (g m^{-2} day^{-1}) and relative growth rate(g g^{-1} day^{-1}) are influenced by different sources of phosphorus. Yield attributes such as number of pods plant^{-1}, number of grains pod^{-1}, seed yield (kg ha^{-1}), stover yield (kg ha^{-1}), and test weight of mung bean also increased significantly due to different sources of phosphorus (Kumar *et al*.,2017). Phosphorus helps to increase grain yield, seed quality, regulate photosynthesis, govern physiological and biochemical processes as well as the development of roots and nodulation which facilitates nitrogen fixation (Muchira *et al*., 2018). Application of phosphorus enhanced dry matter and seed yield of mung bean over control (Uddin et *al*., 2010).

The response to applied P was more pronounced on soils low in available phosphorus than in the other soils. Gradual increase in shoot dry matter yield over control was observed in low, medium and high available P soils at all the P levels, and was found to be statistically significant (Muralidharudu *et al*., 2003). Mung bean plants showed significant variation in respect of plant height, number of branches, number of pods plant^{-1}, number of seeds pod^{-1}, pod length, weight of seeds, seed yield (t ha^{-1}) and stover yield (t ha^{-1}) when phosphorus in different doses were applied (Rahman *et al*., 2015 and Hamza *et al*., 2016). Yadav (2017) reported that with the application of phosphorus, there was a significant increase in total number of nodules on Mung bean as compared to the control. However, the increase in total nodules with 60 kg P_2O_5 ha^{-1} was statistically at par with 40 kg P_2O_5 ha^{-1}. Significantly the highest plant height, seeds pod^{-1} and test weight were observed under the treatment of higher doses of P_2O_5 ha^{-1} over control (Sipai *et al*.,2016). In contrast to this Rani *et al*.(2016) reported that plant height was not affected significantly with phosphorus application.

Parameters of green gram are influenced by graded levels of phosphorous. These parameters were growth parameters like plant height, number of branches plant^{-1}, root dry weight, leaf dry weight, stem dry weight and total dry weight of the plant and yield attributes viz., number of pods plant^{-1}, pod length, seed yield, straw yield, seed index, number of seeds plant^{-1} (Khan *et al.*, 2017). Dry matter of plants at different growth stages increased with increase in doses of phosphorus. Application of phosphorus resulted significant increase in all yield attributing characters *viz*, number of pods plant^{-1}, grains pod^{-1},and length of pod with increasing phosphorus. Phosphorus application accelerates the production of photosynthates and its translocation from source to sink which ultimately reflected for higher values of yield attributing characters. Application of phosphorus increased grain, and straw yield significantly with every increase in dose of phosphorous from 0 to 60kg P_2O_5 ha^{-1} (Dwivedi *et al.*, 2018). Phosphorous application had significant response on seed yield and straw yield production of summer green gram. All the higher doses of P significantly enhanced the seed yield and straw yield production (Dharwe *et al*., 2018).

The effects of P on the yield of mung bean were found to be positive and significant. All the levels of phosphatic fertilizer showed significant impact on mung bean crop compared to the control plots. The application of phosphatic fertilizer at higher doses gave the maximum number of pods plant^{-1}, number of grains pod^{-1}, and grain weight resulting ultimately maximum grain yields (Ali *et al*., 2010). Different phosphorus levels significantly affected the number of days to flowering, grain yield as compared to the control. Different doses of phosphorus fertilizer significantly affect plant height, number of grains pod^{-1}, and number of branches plant^{-1} in mung bean.Variable doses of P produce significantly different seed grain weight. But maturity period was non significantly affected by different phosphorus levels (Karim *et al*., 2014*).*

Yield attributes such as number of pods plant^{-1}, pod setting percentage, grains pod^{-1}, and yield plant^{-1} and grain weight increased significantly with increasing levels of phosphorus from 0 to 80 kg P_2O_5 ha^{-1}. Grain and straw yield increased significantly with increasing levels of phosphorus. Increase in harvest index with phosphorus application is the indication of better translocation of photosynthates from source to sink (singh *et al*., 2018). Plant height, seeds pod^{-1}, seed weight, nodules plant^{-1}, nodules weight plant^{-1}, grain yield and straw yield of mung bean significantly affected by different levels of phosphorous from 0 to 40 Kg P_2O_5 ha^{-1} (Sipai *et al*., 2016).

Plant height is the important component of straw yield and may also affect the grain yield. It is a function of both the genetic makeup of the plant and the environmental conditions which the plant is subjected during the growth. The minimum plant height and number of seeds were recorded in plots where no phosphorus was applied. Maximum number of seeds pod^{-1}

was recorded from higher phosphorous levels. Seed weight, and water use efficiency were significantly affected by phosphorous levels. Biological yield of crop shows overall growth performance of crops. It was influenced by different levels of phosphorus (Khan *et al*.,1999). Phosphorous levels from 0 to 60 kg ha^{-1} significantly affected plant height, number of pods $plant^{-1}$, number of seeds pod^{-1}, biological yield, seed yield, seed weight, and harvest index (Imran *et al*., 2016).

The plant height at maturity is influenced by phosphorus levels(0 to 90 Kg ha^{-1}). The number of pods $plant^{-1}$ is also affected by various phosphorus levels. Number of seeds pod^{-1} is an important parameter that directly imparts in exploiting yield recovery. The number of seeds per pod is significantly affected by different levels of phosphorus. Among various parameters contributing towards economic yield of a crop, grain weight is of prime importance and phosphorous significantly affected grain weight. There is significant nodulation response of mung bean plants treated with different phosphorus levels. All phosphorus levels showed non significant effect on harvest index (Ullah *et al*., 2010).

3. MATERIALS AND METHODS

3.1 Experimental Site Description

An experiment was conducted at Alage Agricultural Technical and Vocational Education and Training (ATVET) College which is located about 217 km south west of Addis Ababa and 32 km west of Bulbula town. It is situated at longitude of 38º30ˈ East and latitude of 07º30ˈ North. It lies at an altitude of 1600 m above sea level in the dry agro-ecology of the south western part of the Ethiopian central rift valley. The area has three distinct seasons, namely main rainy (June to September), short rainy (March to May), and dry(October to February) seasons. Based on ten years data (1996-2005), the mean annual rainfall of the area is 800 mm, with mean minimum and maximum temperatures of 11 and 29ºC, respectively (Addisu ,2007).

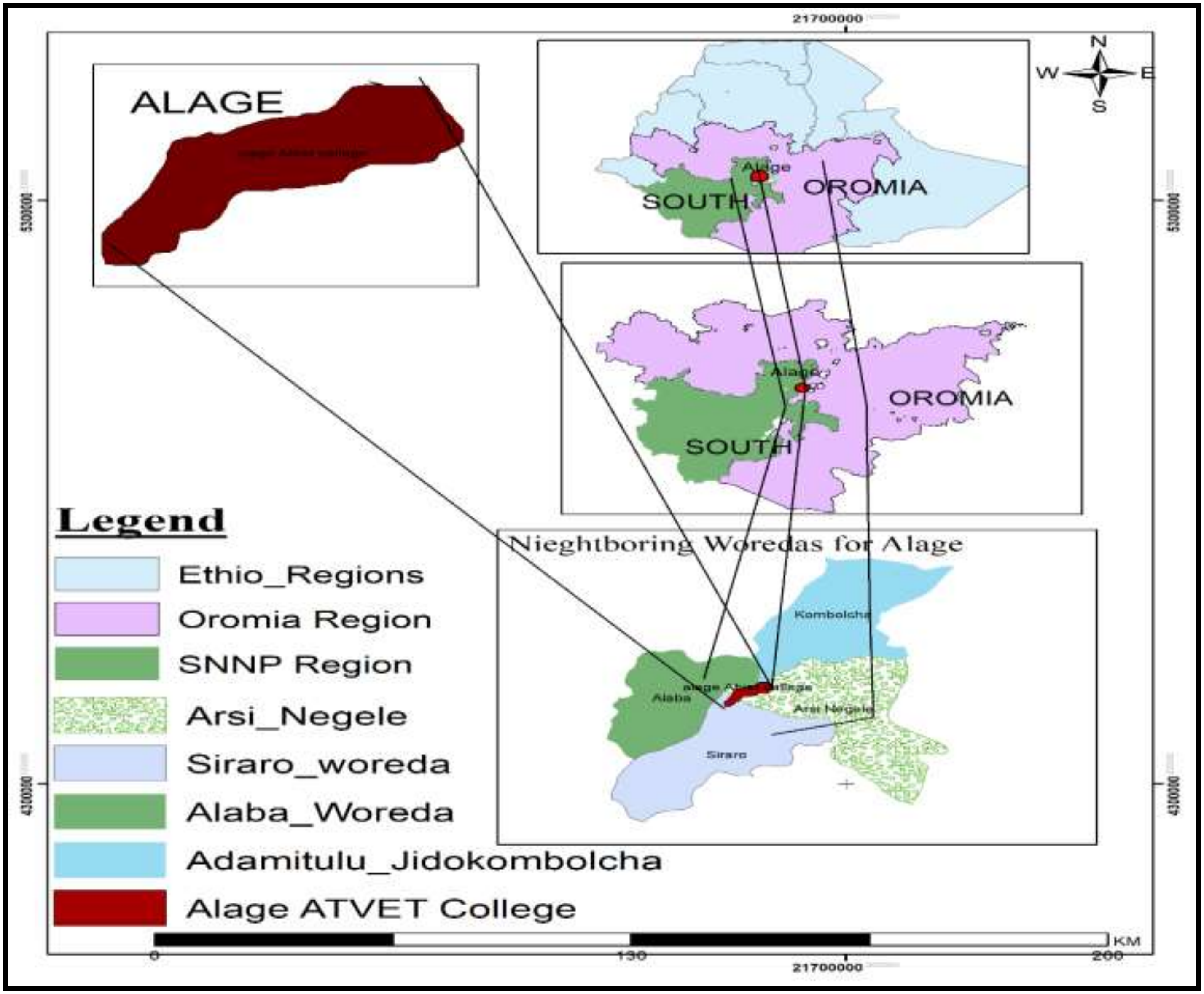

Figure 1: Location map of study area source(GIS)

3.2. Treatments and Experimental Design

The treatments consisted of the factorial combinations of four mung bean varieties(MH-97-6 (Boreda-1), Rasa (N-26), NVL-1) and Shoa robit and four levels of phosphorus(0, 23, 46, 69 Kg P_2O_5 ha^{-1}). The source of P fertilizer was TSP. The treatments were laid out in Randomized Complete Block Design with four replications. The description of the improved varieties are given in table-1. A plot having uniform fertility, and even topography was selected for experimental trial. Finally the lay out was done to meet the requirements of the experimental design. The plot size was 2.5 x 2.1m and were kept 1m and 1.5m apart between plots and blocks respectively.The spacing was 30 and 10cm between rows and plants respectively.

Table 1: Description of improved mung bean varieties

Characteristics	Varieties		
	MH-97-6 (Boreda-1)	**NVL-1**	**Rasa (N-26)**
Altitude(masl)	1100 - 1750	1100 - 1750	900-1700
Rain fall (mm)	500	500	350-550
N:P Fertilizer (kg ha^{-1})	N:18 ; P_2O_5:46	N:18 ; P_2O_5:46	N:18 ; P_2O_5:46
Growth habit	Indeterminate	Determinate	Determinate
Maturity group	Medium	Medium	Medium
Flower Color	White	Yellow	Yellow
Yield in research field(kgha $^{-1}$)	1350	800-1500	800-1500
Yield in farmer field(kg ha $^{-1}$)	1000	500-1000	500-1000
Year of release	2008	2014	2011
Breeder /Maintainer	SARI/AWRC	NirmalPlc/EIAR/MARC	EIAR/MARC

Source: (MARC, 2014)

3.3. Agronomic practices

Three improved Mung bean varieties; which were released by Hawassa Research Centre (MH-97-6 (boreda-1)) and Melkassa Research Centre (Rasa (N-26), and NVL-1), and one local variety called Shoa robit were used for the experiment. Phosphorous was applied at 4 rates or levels of application(0, 23, 46, and 69 Kg P_2O_5 ha^{-1}). The source of phosphorous fertilizer was TSP and all the required amounts of phosphorus were applied in band method of application at planting time. Nitrogen was applied at rates of 18 Kg N ha^{-1} and the source of the fertilizer was Urea. Urea was applied in split methods of application two times; half of the rates were applied at time of sowing as starter fertilizer in bands beside seed rows; and the rest were applied after 3 weeks of the first application.

3.4. Soil sampling and analysis

Pre-planting soil samples were taken randomly in a zigzag fashion from the experimental field at the depth up to 20cm. Ten soil samples were taken by an auger from the whole experimental field and combined to form a composited sample. From this mixture, a sample weighing one kg was filled in to a plastic bag and prepared for the analysis.

The soil was air dried and sieved through a 2mm sieve. Then, soil pH was determined by diluting the soil in a 0.01 M $CaCl_2$ solution in the ratio of 1 soil volume to 2.5 volume of the $CaCl_2$ solution. Thus, twenty-five ml of the 0.01M $CaCl_2$ solution was added into soil sub samples each weighing 10g. After equilibrating for 2-3 hours, the suspensions were filtered and the pH measured by a glass electrode. Texture of the soil was determined by sedimentation method (Hesse, 1971). The soil samples were analyzed for total nitrogen, exchangeable potassium, and available phosphorous and organic carbon. Total nitrogen of the soil was determined by the

Kjeldhal procedure (Bremner,1959). Organic carbon was determined by the method of Nelsen and Sommers(1982). Available phosphorous content of the soil was determined by extraction with 0.5M NaHCO3 (Olsen *et al*., 1954). Phosphorus in the extracts was determined with atomic absorption spectrophotomer calorimetrically according to the molybdenum blue color method of Murphy and Riley (1962).

3.5. Data Collection

3.5.1. Phenological parameters

Days from planting to flowering was recorded by counting the number of days when 50% of the plants plot^{-1} had the first open flowers. Number of days taken from planting to maturity was also recorded when 90% of pods are matured plot^{-1}.

3.5.2. Nodule and growth parameters

Number of nodules plant^{-1} were counted after five plants were selected randomly in sample rows of each plot and uprooted carefully. The soil mass embodying the roots of the plants were then removed and the total root nodules were counted to record average number of nodules plant^{-1}. Nodule dry weight plant^{-1} were calculated after the total root nodules obtained from five randomly selected plants from each plot were oven dried at 70^0 C for 48 hours. After complete drying, the material was weighed on sensitive balance, and then average was written as nodules dry weight plant^{-1}. Dry weight of roots plant^{-1} were taken after five randomly selected plants were uprooted and the soils embodying the roots were removed, oven dried and weighed.

Plant height was measured in centimeters from the ground level to the top of the plant at physiological maturity of five randomly selected plants from each plot. The total number of branches were counted at physiological maturity from five randomly selected plants plot^{-1} and the average was calculated as number of branches plant^{-1}. To find out the effect of different treatments on shoot dry weight plant^{-1} of the crop, five plants were randomly uprooted from rows of each plot. After removing the root portion, the above ground parts of the five plants were dried in an electric oven at 70°C for 72 hours, and was weighted on balance and recorded.

3.5.3. Yield and Yield Related Characters

The pods of five randomly selected plants were counted and the average was worked out and recorded as number of pods plant^{-1}. Number of seeds pod^{-1} was recorded at harvest by counting the number of seeds of five randomly selected pods from five plants and the average number of seeds pod^{-1} was calculated. The grain yield was harvested from three central rows (2.25m^2 area) for five rounds. The grain yield was adjusted to 10% moisture content. Selected central rows were harvested and weighed the total biomass as biological yield of the treatment by adding with seed yield of that rows and converted into t ha^{-1}. Hundred seed weight was taken from hundred seeds of plants from each plot and were weighted using a digital balance. Harvest index was expressed as the ratio of mature seed yield to the total biological yield.

$$\text{Harvest Index} = \frac{\text{Economic yield (t ha}^{-1}\text{)}}{\text{Biological yield (t ha}^{-1}\text{)}} * 100\% \quad \text{(Ismail (1993))}$$

3.6. Statistical Analysis

The growth ,nodule and yield and yield related data were subjected to analysis of variance using 9.0 version of SAS soft ware. The means that differ significantly were separated using the LSD procedure at 5% level of significance. Correlation coefficient was also determined for important parameters.

3.7. Economic analysis

An economic analysis was done using partial budget procedure as described by CIMMYT (1988) in which prevailing market prices for inputs at planting and for outputs at harvesting were used. The following were some of the parameters quantified. Unadjusted grain yield (UGY) (kg ha^{-1}) is an average yield of each treatment. Adjusted grain yield (AGY) (kg ha^{-1}) is the average yield adjusted down ward by 10% to reflect the difference between the experimental yield and yield of farmers. Gross field benefit (GFB) (ETB ha^{-1}) was computed by multiplying field/farm gate price that farmers receive from the crop when they sell it as adjusted yield.

GFB = AGY × field/farm gate price for the crop.

Total variable cost (TVC)(ETB ha^{-1}) were calculated by summing up the costs that vary, including the cost of TSP fertilizer(14.5 ETB) ,cost for fertilizers application, and the price of mung bean seeds at market(35 ETB). The net field benefit (NFB) were calculated by subtracting the total variable costs (TVC) from gross field benefits (GFB) for each treatment.

NFB = GFB – TVC

Marginal rate of return were calculated by dividing change in net benefit (ΔNFB) by change in total variable cost (ΔTVC) then multiplied by 100. The treatment with highest net benefit and MRR > 100 was considered for recommendation.

4. RESULT AND DISCUSSION

4.1. Soil physico-chemical properties of the experimental site

The soil physico-chemical properties of experimental site were determined before sowing as shown in Table-3. The soils in the study area are silty loam in textural class. According to Walkley and Black (1934) ranking, organic carbon (OC) <1.2% is categorized as low, 1.2-2% is categorized as moderate , and more than 2% as high. The organic carbon of the soils in study area was high. Soils are classified depending on their percent of total nitrogen content, as very low (<0.1), low (0.1-0.15), medium (0.15-0.25), and high (>0.25) (Havlin *et al*., 1999). Thus, the soils of the study area have low nitrogen content. Olsen P rating shows very low(<3 mg kg^{-1}), low (4-7 mg kg^{-1}), medium (8-11.5 mg kg^{-1}), high (>12mg kg^{-1}) as described by Havalin *et al*. (1999). The available P content of the soil in study area was medium.

According to the ratings of Landon (1991), top soils having CEC of >25, 15-25 cmol (+) kg^{-1}, 5-15 cmol (+) kg^{-1} and <5 cmol (+) kg^{-1} classified as high, medium, low and very low, respectively. The cations exchange capacity (CEC) of the soils in study area categorized as high. Soil pH has strong effects on nutrient availability. Soil pH of the study area was slightly alkaline.

Table-2: Physio-chemical properties of soils of the experimental site

Parameters	Methods	Unit	Values
Sand		%	32
Silt		%	51.5
Clay		%	18.5
Textural class	Bouycos hydrometer		Silt loam
pH	pH meter	pH(H_2O)	7.8
OC	Walkley and Black	%	2.3
TN	Kjeldahl	%	0.12
EC	Electro Conductivity meter	ds m^{-1}	0.34
Av.P	Olsen method	mg kg^{-1}	11.24
Av.K	Ammonium acetate (1MN4OAC)	mg kg^{-1}	570
CEC	Ammonium acetate (1MN4OAC)	cmol kg^{-1}	32.74

NB: TN = Total nitrogen,OC=Organic Carbon, EC = Electrical conductivity, AV.P = Available Phosphorus, AV.K = Available potassium, CEC =cat-ion exchange capacity.

4.2. Effect of Phosphorus application and variety on phenological parameters of mung bean

4.2.1 Days to flowering

The mung bean varieties showed significant variation in days to flowering of mung bean ($p<0.05$). The variety boreda-1 was the latest in days to flowering(42days) which was statistically similar with variety shoa robit(42days). Varieties(Rasa and NVL-1) were earlier which takes 40 days for flowering and were statistically similar. The same result was observed by Imran *et al.(*2016), Tarikua(2017), and Habte(2018) who noted that varieties significantly affected days to flowering of mung bean crop.

In the present study P levels also significantly($p<0.001$) affected days to flowering of mung bean crop(Table-3). Among fertilizer rates 46kg P_2O_5 ha^{-1} was earlier in days to flowering(40 days);but was statistically similar with 69 Kg P_2O_5 ha^{-1}(40 days). The latest was recorded at 0 kg P_2O_5 ha^{-1} (43 days) rates of phosphorous fertilizer. This might be due to phosphorous improves flower formation and seed production. In line with this research finding Geletu and Mekonnen (2018) , Karim *et al*. (2014) and Arebu *et al*. (2019) reported that phosphorous fertilizer rates significantly affected the flowering date of mung bean crop. However, the interaction between phosphorous fertilizer rates and variety in this experiment showed no significant effect on days to flowering(Table-3).

4.2.2. Days to physiological maturity

Analysis of variance showed that days to physiological maturity was significantly($p<0.001$) responded to varieties of mung bean. The variety Boreda-1 took more number of days to maturity(64 days); but was statistically similar with variety shoa robit(64 days). Variety N26 was the earliest(60 days) which was statistically at par with variety NVL-1(62 days). Geletu and Mekonnen(2018) and Mondal *et al*.(2012) also reported that varieties have showed significant differences($p<0.05$) on days to physiological maturity. Tarikua(2017) on mung bean and Gebre-Egziabher *et al*. (2014) on haricoat bean crop reported that variety showed highly significant($P<0.01$) variation on days to physiological maturity. On the other hand, abscence of significant variation among cultivars for maturity duration in mung bean have been reported (Rehman *et al*., 2009 ; Habte, 2018).

Phosphorous fertilizer rates in this experiment showed significant effect on days to maturity (Table-3). The result showed that highest phosphorous rates(69 Kg $P_2O_5ha^{-1}$) took shorter number of days to physiological maturity(61 days) than the control(65days). The reason for higher phosphorous rates to shorten number of days to maturity may be because phosphorous is responsible for crop maturity when applied at the right time. Plants that lack phosphorous take more time to mature(Tajer ,2016). Geletu, and Mekonnen(2018) and Arebu *et al*.(2019) reported that phosphorous fertilizer rates have showed significant effects on days to physiological maturity. Gifole *et al*.(2011) also reported in common bean crop that the level of phosphorous supply had significantly influenced days to physiological maturity. In contrast to this; the maturity period is non significantly affected by different phosphorus levels (Karim *et al*., 2014). The data analysis from the present study showed that there was a non-significant effect of the interaction of phosphorous fertilizer and variety on days to maturity of mung bean crop. This result is in agreement with that of Takele *et al*. (2017) who reported that the interaction among phosphorous fertilizer rates and lentil crop cultivars was non significant.

Table-3: Main effects of phosphorus levels on days to flowering, and maturity of mung bean varieties in 2019, at Alage.

Treatments	DTF	DTM
Varieties		
Boreda-1	42^{a}	64^{a}
N26	40^{b}	60^{b}
NVL-1	40^{b}	62^{b}
Shoa robit	42^{a}	64^{a}
$LSD_{0.05}$	1.56	1.50
P_2O_5 kg ha^{-1}		
0	43^{a}	65^{a}
23	41^{b}	63^{b}
46	40^{c}	61^{c}
69	40^{c}	61^{c}
$LSD_{0.05}$	1.56	1.50
CV (%)	5.37	3.37
P X V	NS	NS

LSD = Least significant difference, CV= coefficient of variations, P*V = the interactions of phosphorus with variety, NS= non significant, DTF=days to flowering, DTM=Days to maturity.Means followed by the same letter within the column are not significantly different at $P<0.05$.

4.3.Effect on Nodule and Growth parameters of mung bean crop

4.3.1. Number of nodules plant^{-1}

Analysis of variance of the present study showed that there was significant response of mung bean varieties for number of nodules plant^{-1}($p<0.01$)(Table-4). The variety N26 produced more number of nodules plant^{-1}(20.16) but was statistically similar with NVL-1(19.98). The lowest was recorded from Shoa robit local(16.28). This is in agreement with Madhu (2013), Geletu,and Mekonnen(2018), and Gebre-Egziabher *et al*.(2014) who reported that varieties differed significantly from each other in nodules number plant^{-1}. In contrast, Tarikua (2017) and Ullah *et al*.(2010) reported that number of nodules plant^{-1} revealed no significance difference among different varieties of mung bean.

Phosphorous fertilizer rates also showed significant difference for nodules number plant^{-1} ($p<0.01$). Maximum number of nodules plant^{-1} was recorded from 69Kg P_2O_5 ha^{-1}(20.91) and the minimum was from the control(15.69). The reason for this significant difference may be because phosphorus helps in better nodulation and efficient functioning of nodule bacteria for fixation of nitrogen. Similar results were reported by Jackson(2014) on soybean , and Arebu *et al*. (2019) on mung bean who reported that phosphorous fertilizer rates have showed significant effects on nodules number plant^{-1}. Amare *et al*.(2014) in haricot bean and Abdul-Aziz(2013) in soybean crop also reported that number of nodules plant^{-1} were significantly affected by phosphorous fertilizer. Yadav (2017) and Sipai *et al*. (2016) observed that with the application of phosphorus, there is a significant increase in total number of nodules plant^{-1} in mung bean crop as compared to the control(0Kg ha^{-1}). Similar to our result, Ullah *et al*. (2010) reported absence of significant variation by the interaction among genotypes and phosphorus levels on nodules number plant^{-1} in mung bean. In contrast, Amare *et al*.(2014) observed that nodules number was significantly($P<0.01$) affected by the interactions between variety and phosphorous in haricoat bean crop. The variation in the reported results could be attributed to differences in soil, genotype and species composition, and soil and weather conditions.

4.3.2. Dry Weight of Nodules plant^{-1}

Analysis of variance showed that nodules dry weight plant^{-1} was significantly($p<0.001$) affected by main effects of variety, phosphorous levels and by their interaction(Appendix table-2). The highest nodules dry weight(0.42g plant^{-1}) was recorded from variety NVL-1 and the lowest was from shoa robit (0.34g plant^{-1}) ;but was statistically similar with boreda-1(0.34g plant^{-1})(Fig.2). Similar to this result, Das (2017) on common bean reported that there is significant difference in the dry weight of nodules plant^{-1} among different varieties. On the contrary; Abdul-Aziz (2013) and Aziz *et al*. (2016) reported that variety had no significant($P>0.05$) effect on nodules dry weight of soybean crop.

In the present study, phosphorous fertilizer rates of 46 Kg P_2O_5 ha^{-1} recorded the highest nodules dry weight(0.40g plant^{-1}) and the lowest was from 0 Kg P_2O_5 ha^{-1} (0.34g plant^{-1}). In line with this, Rekha *et al*. (2018) observed that dry weight of root nodules were significantly increased with increasing phosphorous levels from 20 to 40 kg P_2 O_5 ha^{-1}. Jackson (2014) on soy bean, and Arebu *et al*. (2019) on mung bean also reported that different phosphorus fertilizer rates significantly($P<0.05$) affected nodules dry weight. Yumnam *et al*. (2018) also reported application of phosphorus showed marked improvement and significant difference in dry weight of nodules plant^{-1} over control for lentil crop.Analysis of variance also showed that there was significant response of mung bean crop by the interaction of variety and phosphorous fertilizer rates. The varieties N26 and NVL-1 at 46 and 69 Kg P_2O_5 ha^{-1} produced heavier dry weights of nodules plant^{-1} and the lower dry weights were obtained from all cultivars at control fertilizer rate(Fig.2). More importantly, only cultivars N26 and NVL-1 responded to P fertilizer application while the remaining two did not show a response. Differently,Abdul-Aziz(2013) on soy bean crop and Takele *et al.* (2017) on lentil crop reported that the interactions of variety and phosphorous fertilizer rates had no significant effect on nodules dry weight.

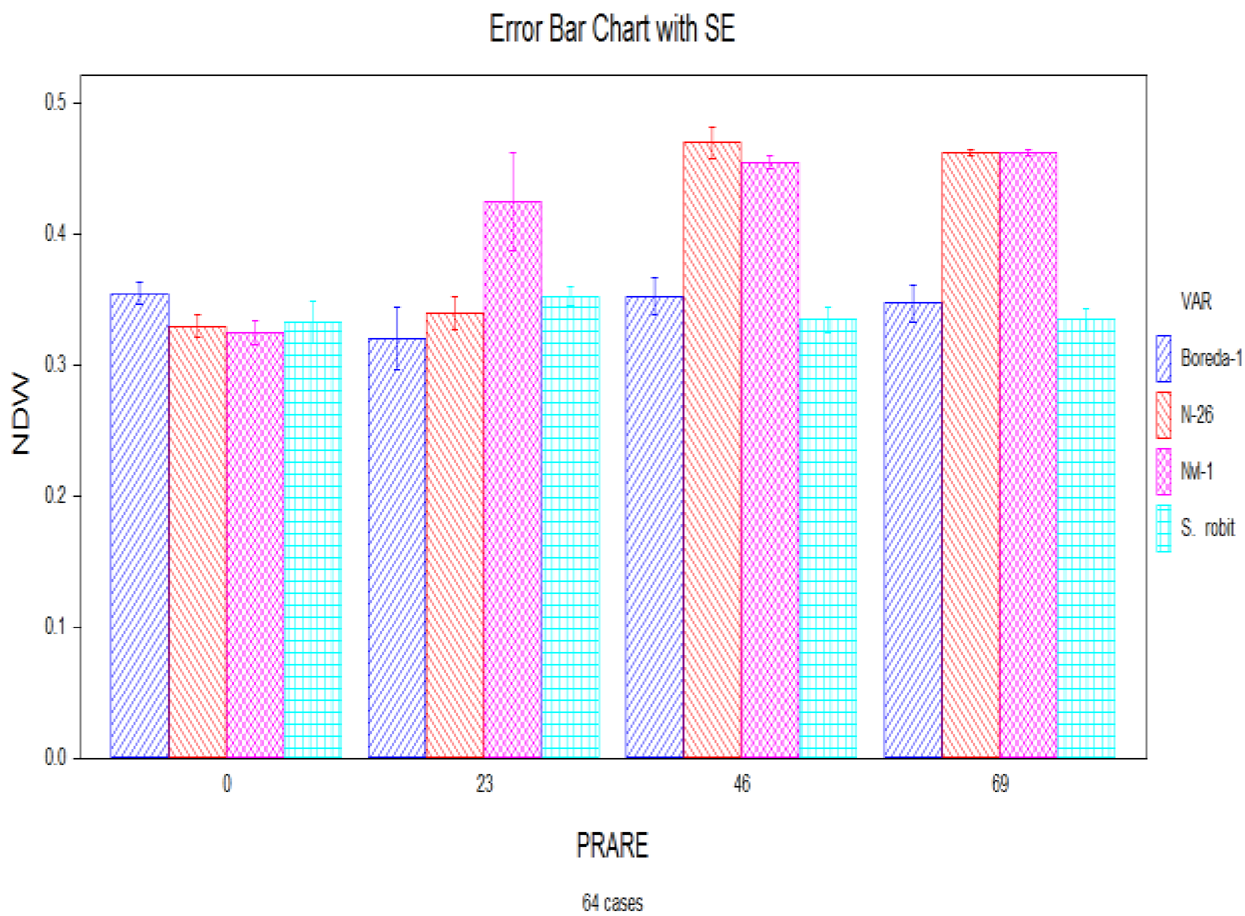

Figure 2: The interaction effects of variety and phosphorous on nodules dry weight plant^{-1} of mung bean crop.

Where NDW= nodule dry weight, var=variety

4.3.3. Root dry weight plant^{-1}

Analysis of variance showed that mung bean varieties differ significantly for dry weight of roots plant^{-1} ($p<0.05$)(Table-4). The variety NVL-1 produced the highest root dry weight(4.07 g plant^{-1}) which was statistically similar with variety N-26 (4.05 g plant^{-1}) ; but the lowest root dry weight (3.73 g plant^{-1}) was recorded by variety shoa robit(Table-4). Similar results were also explained by Jaidee *et al*.(2012) who reported that soybean cultivars had significantly different root dry weights. In the present study; phosphorous fertilizer application in different rates also showed significant difference in Mung bean for root dry weight($p<0.01$)(Table-4). Significantly highest root dry weight was recorded from phosphorous fertilizer rates of 69 Kg P_2O_5 ha^{-1}(4.17g plant^{-1}) followed by 46 Kg P_2O_5 ha^{-1}(3.91g plant^{-1}) and the lowest root dry weight was from the control(3.64g plant^{-1}) (Table-4). The reason may be that phosphorous boosts the development of the roots necessary for the plant to get nutrients from the soil (Tajer , 2016). These results were confirmed by the findings of Khan *et al*. (2017) and Bhuiyan *et al*. (2008) who observed that the difference in the root dry weight of Mung bean is significant due to different levels of phosphorous.

Table-4: Main effects of phosphorous on nodules number and root dry weight of mung bean varieties in 2019, at Alage.

Treatments	NN	NDW(g plant^{-1})	RDW(g plant^{-1})
Varieties			
Boreda-1	16.82^{b}	0.34^{c}	3.77^{b}
N26	20.16^{a}	0.36^{b}	4.05^{a}
NVL-1	19.98^{a}	0.40^{a}	4.07^{a}
Shoa robit	16.28^{b}	0.40^{a}	3.73^{b}
$LSD_{0.05}$	2.47	0.02	0.25
P kg ha^{-1}			
0	15.69^{c}	0.34^{b}	3.64^{c}
23	18.29^{b}	0.40^{a}	3.90^{b}
46	18.35^{b}	0.42^{a}	3.91^{b}
69	20.91^{a}	0.34^{b}	4.16^{a}
$LSD_{0.05}$	2.47	0.02	0.25
CV (%)	18.94	7.73	8.94
P X V	NS	0.04	NS

LSD = Least significant difference, CV= coefficient of variations, P*V = the interactions of phosphorus with variety, NS= non significant, NN=Nodule number, RDW=Root dry weight per plant.Means followed by the same letter within the column are not significantly different at $P<0.05$.

4.3.4. Plant height

Analysis of variance showed that there was significant difference among mung bean varieties for plant height($p<0.001$)(Table-5). The longest plant height was recorded from variety boreda-1(51.15cm); but was statistically similar with shoa robit(48.93cm)(Table-5). The shortest plant height was recorded from variety N26(rasa)(42.7cm). In line with this finding, Geletu,and Mekonnen (2018), Mondal *et al*. (2012), Imran *et al*. (2016) and Madhu(2013) reported that the variation among varieties for plant height is significant. Khan *et al*. (2017) and Fantaye *et al*. (2019) found that there is highly significant differences($P=0.01$) among the genotypes for plant height. Amare *et al*.(2014) also reported significant differences($P<0.01$) in plant height among varieties of haricot bean crop. These findings are in contradiction with those reported by Ullah *et al.(*2010) and Rehman *et al*.(2009) that the differences of plant height is non significant among different cultivars. Aziz *et al*. (2016) , and Abdul-Aziz (2013) on soya bean crop also obtained non significant ($P>0.05$) effect of varieties on plant height.

Analysis of variance also showed that plant height was significantly affected by phosphorous fertilizer rates. The highest plant height was recorded from p rates of 46 Kg P_2O_5 ha^{-1}(51.93cm) and the lowest was recorded from the control(40.24cm). The reason for this may be that phosphorus plays a key role in plants that enough phosphorous helps all parts become well developed and grow quickly (Tajer, 2016). In agreement to this finding, Imran *et al*. (2016), Singh *et al*. (2017) , Rekha *et al*. (2018), and Rahman *et al*. (2015) showed that P levels significantly affected plant height of mung bean crop. Plant height increased significantly as the rates of phosphorous increased in common bean crop(Mesfin *et al*., 2014). Application of phosphorus resulted in significant increase in plant height at different stages of growth up to 60 kg P_2O_5 ha^{-1}(Dwivedi *et al*., 2018). In contrast to this result, Nikfarjam *et al*. (2015), Rani *et al*.

(2016), and Gifole *et al*. (2011) observed that plant height is not significantly affected by phosphorus application. The interaction between phosphorus and variety showed non significant difference among treatments for plant height.The same result was reported by Imran *et al*.(2016) that the interaction between variety and phosphorous on plant height showed non significant effect in mung bean crop.

4.3.5. Number of primary branches plant^{-1}

The results from data analysis showed that there was significant($p<0.001$)(Table-5) effect of varieties on number of primary branches plant^{-1} in mung bean crop. The maximum number of branches plant^{-1} were obtained from variety boreda-1(6.14) followed by shoa robit(5.48) and the lowest was recorded from variety N26(4.78) (Table-5). Variation in number of primary branches plant^{-1} might have occurred due to the differences in genetic make-up of the tested varieties. Similarly, Achakzai *et al*.(2012), Madhu (2013) , and Dwivedi *et al*. (2018) reported that branches number plant^{-1} differed significantly among the studied varieties. In contrary to this, Tarikua (2017) obtained non significant effect of variety on the number of primary branches plant^{-1}.

In case of phosphorous fertilizer rates, treatments fertilized with 69kg P_2O_5 ha^{-1} produced higher number of branches plant^{-1} (6.42) and the treatment not fertilized produced the lowest(4.25) number of branches plant^{-1} (Table-5). The reason may be due to phosphorus supplying might have stimulated the rate of various physiological process favouring increased growth and yield attributes(Verma *et al*., 2017). Similar to this research finding, Gautam (2017), Rahman *et al*. (2015), and Hamza *et al*. (2016) reported that number of branches plant^{-1} varied significantly due to the different levels of phosphorus. Similarly, Geletu and Mekonnen (2018) and Bhuiyan *et* *al*.(2008) reported phosphorous levels have showed significant effects ($p < 0.05$) on number of branches plant^{-1}. Meseret ,and Amin (2014) reported that the application of phosphorous fertilizer significantly affected the number of branches plant^{-1} in haricoat bean crop. In contrasts, Khan *et al*.(2017) found that different levels of phosphorus has non significant effect on branches number plant^{-1}. In the case of the interaction of mung bean varieties and phosphorous fertilizer rates, significantly ($p<0.05$) maximum number of branches plant^{-1} was recorded from the interaction of variety boreda-1 with p rates of 69 Kg P_2O_5 ha^{-1}(7.51) and the lowest was from the interaction of variety NVL-1 with control (4.07)(Fig.3). Similarly,Mesfin *et al*.(2014) on haricot bean crop reported that the interaction of varieties and phosphorous fertilizer rates significantly affected number of branches plant^{-1}. In contrary to the present result, Takele *et al*.(2017) reported that the number of branches plant^{-1} were not significantly affected by the interaction of variety of lentil crop with phosphorous fertilizer rates.

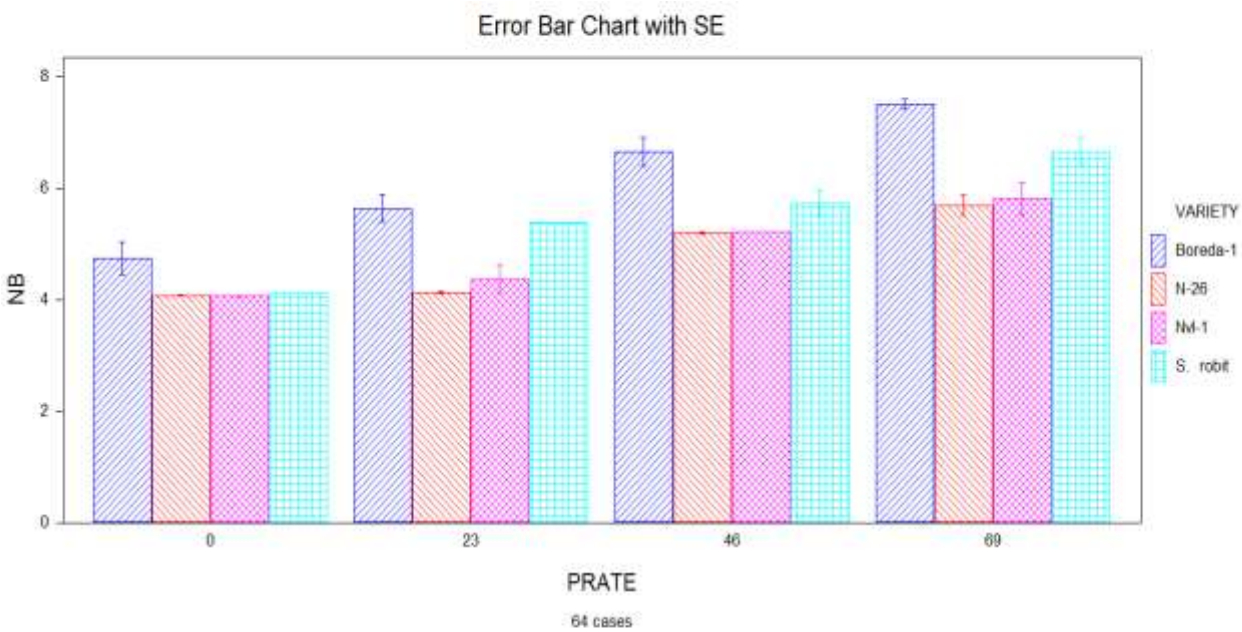

Figure 3**:** The interaction effects of variety and phosphorous on number of branches plant^{-1} of mung bean crop.

Where NB=number of branches

4.3.6. Shoot dry weight plant^{-1}

The results from this research finding showed that mung bean varieties and phosphorous application significantly affected shoot dry weight of mung bean crop($p<0.001$)(Table-5). Significantly highest shoot dry weight(19.93 g plant^{-1}) was recorded from variety boreda-1 followed by shoa robit (17.71 g plant^{-1}) ; but the lowest was recorded from variety Rasa (N-26) (12.67 g plant^{-1}). The present finding was supported by Jaidee *et al*. (2012) who reported soybean cultivars were significantly differ in shoot dry weight. These findings are in conflict with the results of Aziz *et al*. (2016) and Abdul-Aziz (2013) who reported shoot dry weight (biomass) at mid-flowering was not significantly influenced by varieties of soy bean.

In case of phosphorous fertilizer rates, the highest shoot dry weight was recorded from 46 Kg P_2O_5 ha^{-1} (19.17 g plant^{-1}) and the lowest was from the control(12.19 g plant^{-1}). The reason may be due to phosphorus supplying might have stimulated the rate of various physiological process favouring increased growth and yield attributes(Verma *et al*., 2017). This research results were also supported by Khan *et al*. (2017) on mung bean,Abdul-Aziz (2013) and Jaidee *et al*. (2012) on soybean who reported that the differences in the dry weight of the plant due to levels of phosphorus was significant. Bhuiyan *et al*.(2008) also found significant effect of phosphorous on shoot dry weight of mung bean. Jackson (2014) on soybean and Arebu *et al*. (2019) on mung bean observed that phosphorus fertilizer rates response were highly significant($p<0.05$) on shoot biomass.

Table-5: Main effects of phosphorous on growth parameters of mung bean varieties in 2019,at Alage.

Treatments	Plant Height(cm)	Number of Branches	Shoot Dry Weight(g plant^{-1})
Varieties			
Boreda-1	51.15^{a}	6.14^{a}	19.93^{a}
Rasa(N-26)	42.70^{b}	4.78^{c}	12.67^{d}
NVL-1	44.69^{b}	4.87^{c}	15.29^{c}
Shoa robit	48.93^{a}	5.48^{b}	17.71^{b}
$LSD_{0.05}$	3.48	0.25	1.71
P kg ha^{-1}			
0	40.24^{c}	4.25^{d}	12.19^{c}
23	47.55^{b}	4.88^{c}	15.37^{b}
46	51.93^{a}	5.70^{b}	19.17^{a}
69	47.75^{b}	6.42^{a}	18.88^{a}
$LSD_{0.05}$	3.48	0.25	1.71
CV (%)	10.43	6.72	14.65
PXV	NS	0.51	NS

LSD = Least significant difference, CV= coefficient of variations, P*V = the interactions of phosphorus with variety, NS= non significant, PH=plant height, NB=number of branches per plant, SDW=shoot dry weight per plant.Means followed by the same letter within the column are not significantly different at $P<0.05$.

4.4. Yield and Yield Components of Mung Bean Crop

4.4.1. Number pods plant^{-1}

Analysis of variance showed that varieties effects was significant($p<0.001$) on number of pods plant^{-1}. Higher number of pods plant^{-1} were recorded from variety boreda-1(36.71) followed by N26 (34.38) and the lowest number of pods plant^{-1} was recorded from variety NVL-1(23.86). The reason for this significant difference might be due to the differences in the genetic make up of the tested varieties. Similarly, Habte (2018), Imran *et al*.(2016), Madhu (2013), and Zahan *et al*.(2016) reported that cultivars significantly affected number of pods plant^{-1}. Gebre-Egziabher *et al*. (2014) also found significant differences ($P<0.001$) among haricoat bean varieties for number of pods plant^{-1}. Khan *et al*. (2017) found highly significant differences($P=0.01$) among the genotypes for number of pods plant^{-1}. In contrast, Khan *et al*.(2015), Fantaye *et al.* (2019) and Rehman *et al*. (2009) obsevred no significant difference on number of pods plant^{-1} among mung bean cultivars.

The results from data analysis showed that phosphorous fertilizer rates of 69 Kg P_2O_5 ha^{-1} produced higher number of pods plant^{-1} (32.69) followed by 46 Kg P_2O_5 ha^{-1} (31.02) and the lowest was from 0Kg P_2O_5 ha^{-1}(26.52). The reason for higher phosphorus rates produce more number of pods plant^{-1} might be P plays a key role in pod filling and ultimately enhances the production (Karim *et al*., 2014). Similarly, Gautam(2017), and Imran *et al*.(2016) reported that phosphorous levels significantly affected number of pods plant^{-1}. Ullah *et al*. (2010) also found that mung bean crop showed highly significant response to phosphorus fertilization on number of pods plant^{-1}.In contrast,Khan *et al*.(2015) found that number of pods plant^{-1} showed no significant variation for the different phosphorous levels.

Analysis of variance showed that there was significant difference by the interaction of variety and phosphorous fertilizer rates($p<0.01$). Significantly higher number of pods plant^{-1} was recorded from the interaction of variety Boreda-1 with 69 Kg P_2O_5 ha^{-1} (39.38) ,but it was statistically similar with other interactions such as the interaction of variety Boreda-1 with 23 and 46 Kg P2O5 ha^{-1} and variety Rasa(N-26) with 23 and 69 Kg P2O5 ha^{-1}. While the lowest was from the interaction of variety NVL-1 with the control (21.09) though statistically at par with the interaction of this variety with 23 Kg P2O5 ha^{-1} (Fig.4). The interaction also showed that the varieties Boreda-1 and N26 repsonded more to P application compared to the control, than the remaining two varieties. This result is in agreement with that of Khan *et al.* (1999) who reported that number of pods plant^{-1} significantly influenced by the interaction of different levels of phosphorus and varieties of mung bean. Amare *et al*.(2014) on haricot bean also reported that application of phosphorus at 40 kg P_2O_5 ha^{-1} produced the maximum significant pods number (19.011) while the lowest number of pods(12.944) was obtained from the control. Conversly, Ullah(2010),and Imran *et al.* (2016) reported that the interaction effect of P fertilizer and mung bean cultivars for number of pods per plant was non significant .

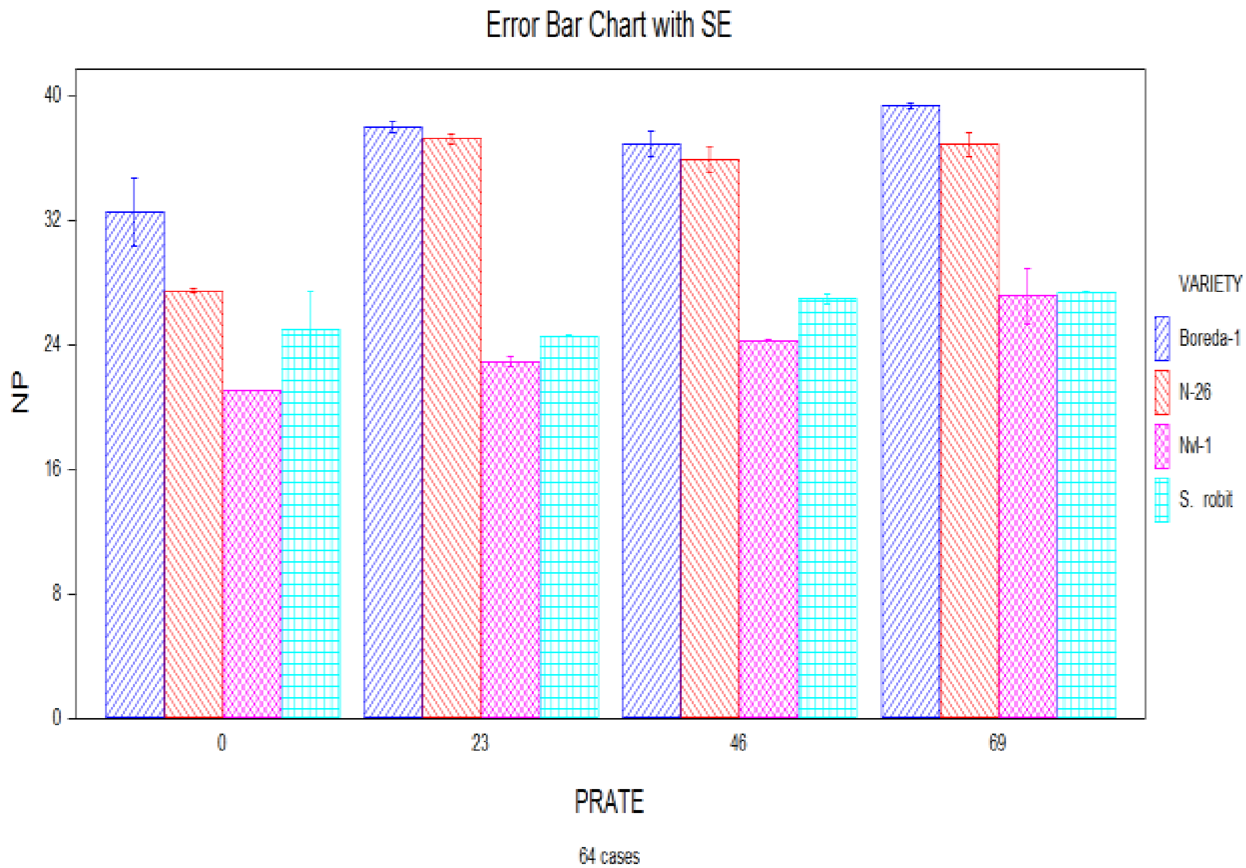

Figure 4: The interaction effects of variety and phosphorous on number of pods plant^{-1} of mung bean crop.

Where:NP=number of pods plant^{-1}

4.4.2. Number of seeds pod^{-1}

Analysis of variance showed that varieties had shown significant variation($p<0.05$) in number of seeds pod^{-1} of mung bean crop(Table-6). Higher number of seeds pod^{-1} was recorded from variety Boreda-1(12.46) ;but was statistically similar with variety Rasa(N-26)(12.46) and the lowest was from variety NVL-1(12.04). In line with this research finding, Habte (2018) , Zahan *et al*. (2016), Khan *et al*. (2015), Hussain *et al.* (2011), Khan *et al*. (2017), and Madhu (2013) reported that number of seeds pod^{-1} showed significant differences among the tested varieties. Tarikua(2017) also reported that variety MH-97-6 had significantly higher number of seeds pod^{-}

[1] (10.08) than variety N-26 (9.41). Contrary to this, Rehman *et al*. (2009) showed that different varieties showed non significant difference on number of grains pod^{-1} in mung bean.

In case of phosphorous fertilizer rates, significantly($P<0.001$) higher number of seeds pod^{-1} was recorded from 46Kg P_2O_5 ha^{-1}(12.52),and the lowest was from 0 Kg P_2O_5 ha^{-1}(11.82) (Table-6). The reason for the significant difference may be that phosphorus is required in relatively large quantities for seed production(FAIAT,2019). Similarly Dwivedi *et al*.(2018), Yadav(2017), Rani *et al*.(2016), and Bandani *et al*.(2014) reported that number of seeds pod^{-1} is significantly affected by phosphorous levels. Karim *et al*.(2014) found that various phosphorus levels(0-100 Kg P ha^{-1}) had highly significantly affected the number of grains pod^{-1}. Meseret , and Amin (2014),and Mesfin *et al*. (2014) also found that seeds pod^{-1} showed significant response to phosphorous levels in haricoat bean crop. Rahman *et al*.(2015) found number of seeds pod^{-1} increased with P levels from 0-20 kg ha^{-1} then declined. In contrst with the present study, Khan *et al*.(2015) observed that fertilizer application had non significant response on number of seeds pod^{-1}. The present research result showed that the effect of the interaction between variety and phosphorous was non-significant on number of seeds pod^{-1}. Similarly Imran *et al*.(2016) reported that the effect of interaction of phosphorous fertilizer levels and variety is not significant.

4.4.3. Grain yield ha^{-1}

The data from this research revealed that varieties ($p<0.001$) influenced grain yield of mung bean (Table-6). The higher grain yield was recorded from variety boreda-1(1.51 t ha^{-1}) followed by N26 (1.42 t ha^{-1}) and the lowest was from NVl-1(1.27 t ha^{-1}). Varietal differences revealed that, the mung bean genotypes used in the present study possessed a high variability and are genetically diversified for grain yield. Similar to this finding, Kabir and Sarkar(2008) , Ahmad *et* *al*. (2003), Fantaye *et al.* (2019), Dwivedi *et al*. (2018) and Mondal *et al*. (2012) observed significant variation in seed yield among different varieties of mung bean. Wedajo (2015) also reported highly significant difference between varieties for seed yield. The highest seed yield was recorded from variety MH-97-6(Boreda-1) followed by N-26, and Shewarobit. Different from the present investigation, Rehman *et al*.(2009) on mung bean,and Abdul-Aziz (2013) on soy bean observed varietal differences to be non significant ($p<0.05$) for grain yield.

In case of phosphorous fertilizer rates, grain yield was significantly increased with increasing phosphorous fertilizer rates up to 46 Kg P_2O_5 ha^{-1} ($p<0.001$)(Table-6). The higher grain yield was obtained from 46 Kg P_2O_5 ha^{-1}(1.5 t ha^{-1}) followed by 69 Kg P_2O_5 ha^{-1}(1.41 t ha^{-1}) fertilizer rates though statistically at par. The lowest grain yield was recorded from the control(1.28 t ha^{-1}). The increase in grain yield with P application might be due to the increase in source capacity viz., plant height, branches $plant^{-1}$ and dry matter accumulation as well as sink capacity viz., pods $plant^{-1}$, grain number $plant^{-1}$. Moreover, it could be attributed to the role of P towards better utilization of photosynthate towards sink formation(Singh , 2018). Similarly,Sipai *et al*.(2016), Serawat *et al*. (2018), Karim *et al*. (2014), and Khan *et al*. (2017) reported that grain yield of mung bean is significantly affected by different phosphorous levels. Khan *et al*. (1999) also reported that application of 60, 90, and 120 kg P_2O_5 ha^{-1} resulted in highest yields that were statistically similar.While, minimum seed yield recorded from the control. Dwivedi *et al*. (2018) obtained that application of phosphorus fertilizer increased grain yield significantly with every increase in dose of phosphorous upto 40 kg P_2O_5 ha^{-1}. The present research result showed that the effect of the interaction between variety and phosphorous was non-significant on grain yield of mung bean crop.

Table-6: Main effects of phosphorous and variety on number of seeds pod^{-1}, and grain yield ha^{-1} of mung bean crop, in 2019, at Alage.

Treatments	NPPP	NSPP	Grain Yield(t ha^{-1})
Varieties			
Boreda-1	26.52^{c}	12.46^{a}	1.51^{a}
N26	30.69^{b}	12.46^{a}	1.42^{b}
NVL-1	31.02^{b}	12.04^{b}	1.27^{c}
Shoa robit	32.69^{a}	12.09^{b}	1.33^{c}
LSD$_{0.05}$	1.41	0.33	0.078
P kg ha^{-1}			
0	36.71^{a}	12.19^{b}	1.28^{c}
23	34.38^{b}	11.82^{c}	1.36^{b}
46	23 .86^{d}	12.52^{a}	1.5^{a}
69	25.97^{c}	12.52^{a}	1.41^{b}
LSD$_{0.05}$	1.41	0.33	0.078
CV (%)	6.55	3.79	7.96
P X V	2.82	NS	NS

LSD = Least significant difference, CV= coefficient of variations, P*V = the interactions of P with variety, NS= non significant, NSPP=number of seed per pod, GY=grain yield ha^{-1}.Means followed by the same letter within the column are not significantly different at P<0.05.

4.4.4. Biological yield ha^{-1}

The results from the present research showed that variety and phosphorous application had significantly affected biological yield of mung bean crop($p<0.001$)(Table-7). But their interaction was non significant. The highest biological yield was recorded from variety Boreda-1(4.23 t ha^{-1}) but was statistically similar with shoa robit(4.14 t ha^{-1}),and the lower was from N26(3.89 t ha^{-1}). In agreement to the present study, researchers reported that cultivars significantly varied for biological yield in mung bean crop(Imran *et al*., 2016). Khan *et al*. (2017) observed highly significant variation($P=0.01$) among genotypes for biological yield. In contrary to this, Rasul *et al*. (2012) and Khan *et al*. (2015) reported that biological yield is not significantly affected by varieties of mung bean crop.

Statistically higher biological yield was recorded from phosphorous fertilizer rates of 46 Kg P_2O_5 ha^{-1}(4.29 t ha^{-1}); but was statistically at par with 69 Kg P_2O_5 ha^{-1}. The lowest biological yield was obtained from the control(3.81 t ha^{-1}). The reason may be due to the fact that phosphorus fertilizer helps the crop to produce more seed and other reproductive parts that ultimately contributed to total biological yield. Similar to the present research finding other researchers reported that phosphorous application had significantly affected biological yield of the mung bean crop(Khan *et al*., 2015, and Imran *et al*., 2016). Higher rate phosphorous treatments resulted in significantly higher total biomass over the control (Gifole *et al*., 2011). Hamza *et al*. (2016) also reported that phosphorous application had significantly affected biological yield of mung bean crop. In the present finding, the interaction effect between variety and phosphorous rates was showed to be non significant on biological yield of mung bean crop.

4.4.5. Harvest index

The analysis of variance from the present study showed that mung bean varieties significantly affected harvest index($p<0.001$)(Table-7). The highest harvest index was recorded from variety Rasa(N-26)(36.72%) ,but was statistically similar with boreda-1(35.81%). The lowest harvest index was obtained from NVL-1(32.24%). In line with the present research finding, Kabir and Sarkar (2008), and Imran *et al*.(2016) obtained that cultivars significantly affected harvest index. Khan *et al*.(2017) also reported highly significant variation($P=0.01$) among the genotypes for harvest index. Tarikua (2017) reported that variety 'MH-97-6' gave significantly higher harvest index (32.38%) than variety Rasa(N-26) with harvest index of 26.77%. In contrasts, Ullah *et al*. (2010) reported that difference in harvest index is non significant among different cultivars.

In the present research result analysis of variance showed that there was non significant difference among different rates of phosphorous fertilizer and by the interaction of mung bean varieties and P rates for harvest index. Similarly, Amare *et al*. (2014) and Gifole *et al*. (2011) reported that phosphorous fertilizer rates have not produced any significant effect on harvest index of haricot bean crop. Conversly, Daniel, and Tefese (2018),and Khan *et al*.(2017) observed that harvest indices varied significantly($P<0.01$) among phosphorous fertilizer levels in field pea crop. Hamza *et al*. (2016) also reported that various levels of phosphorus have significant effect on harvest index. The interaction among genotypes and phosphorus levels was also non significant. In the same manner various treatment combinations of phosphorous fertilizer by variety has not influenced harvest index(HI) significantly(Ullah *et al.*, 2010).

4.4.6. Hundred Seed weight

Results showed that varieties of mung bean significantly($p<0.05$) affected hundred seed weight(Table-7).Significantly heavier hundred seed weight was recorded from variety Rasa(N-26)(5.06g); but was statistically similar with variety NVL-1(5.04 g). Smallest seed weight was recorded from variety shoarobit(4.73 g). Variation in seed weight between varieties may be attributed to differences in genetic make up of the crop plants. Similarly Tarikua (2017), Yehuala *et al*. (2018),and Abdul-Aziz (2013) reported varietal differences to be significant ($p<0.05$) for seed weight. Gebre-Egziabher *et al*. (2014) obtained that haricot bean varieties had a significant variation among each other for seed weight. Hussain *et al*. (2011), Rasul *et al*. (2012), Zahan *et al*.(2016) , Ahmad *et al*. (2003) and Rehman *et al*. (2009) also reported that different varieties have significantly differed in grain weight. On the other hand,Khan *et al*. (2015) obtained that mung bean cultivars produced seeds of the similar weight with out no significant difference.

Phosphorus fertilizer rates of 69 Kg P_2O_5 ha^{-1} gave heavier seed weight(5.17g) followed by 46 Kg P_2O_5 ha^{-1} (4.9g) and the lowest was from the control(4.63 g). Similarly, Yin *et al*. (2018) reported that seed weight of mung bean significantly increased with kg of P ha^{-1}(0-26 Kg P_2O_5 ha^{-1}). Ullah *et al*. (2010) ,Gautam (2017),Imran *et al.* (2016) also reported that phosphorous fertilizer rates significantly affected grain weight. Karim *et al*. (2014) also reported that the variable doses of P_2O_5(20 to 100kg ha^{-1}) led to production of significantly heavier seeds as compared to control.

Table-7: Main effects of phosphorous and variety on biological yield, harvest index, and hundred seed weight of mung bean crop, in 2019, at Alage.

Treatments	Biological Yield(t ha^{-1})	Harvest Index(%)	HSW(g)
Varieties			
Boreda-1	4.23^{a}	35.81^{a}	4.77^{b}
N26	3.88^{b}	36.72^{a}	5.06^{a}
NVL-1	3.94^{b}	32.24^{b}	5.04^{a}
Shoa robit	4.14^{a}	32.36^{b}	4.73^{b}
$LSD_{0.05}$	0.166	2.16	0.25
P kg ha^{-1}			
0	3.81^{c}	33.77	4.63^{c}
23	3.98^{b}	34.33	4.89^{b}
46	4.28^{a}	34.92	4.90^{b}
69	4.12^{ab}	34.12	5.17^{a}
$LSD_{0.05}$	0.166	NS	0.25
CV (%)	5.75	8.87	7.13
P X V	NS	NS	NS

LSD = Least significant difference, CV= coefficient of variations, P*V = the interactions of phosphorus with variety, NS=non significant, BY=biological yield, HI=harvest index, HSW=hundrad seed weight. Means followed by the same letter within the column are not significantly different at $P<0.05$.

4.5.Correlation Analysis

Correlation coefficients were computed to assess the relationships between growth, yield and yield components of the mung bean varieties at different phosphorous levels(Appendix table-6). Number of nodules plant^{-1} had positive and significant correlation with nodules dry weight (0.49), root dry weight(0.62) and hundred seed weight(0.70) of mung bean crop. Grain yield had positive and significant correlations with plant height (r=0.55), number of branches plant^{-1} (0.52), shoot dry weight(0.5), number of pods plant^{-1} (0.64), number of seeds pod^{-1} (0.37),biological yield (0.49) ,harvest index (0.74). These positive correlations among growth and yield related parameters elucidated that all of them had a cumulative contribution for increasing the grain yield in mung bean.This leads to the conclusion that an increase in those growth and yield related parameters simultaneously increased the total yield. In contrast, days to 90% maturity negatively correlated with yield, which means these factors had negative effect on grain yield. Teame *et al*.(2017) reported that plant height (r=0.80), days to flowering (r=0.38), number of pods plant^{-1} (r=0.95), number of seeds pod^{-1} (r=0.88) and hundred seed weight (r=0.93) are correlated positively with grain yield.

Plant height has positive and significant correlation with number of branches plant^{-1} (0.58), shoot dry weight (0.71) ,number of pods plant^{-1} (0.31), grain yield(0.55) and biological yield(0.85). These results are in agreement with Gebre-Egziabher *et al*.(2014) who reported that plant height had highest positive correlation with number of pods plant^{-1} , grain and biomass yield. Plant height had a negative correlation with days to flowering, seed weight, and nodulation.

4.6 Economic analysis

The highest gross return and net return were recorded from variety boreda-1 which are 47624.22 ETB and 46749.22 ETB respectively. But the lowest gross return and net return were obtained from variety NVL-1 ,with 40044.38 ETB and 39169.38 ETB, respectively. Ahmad *et al*. (2003) and Yehuala(2018) also reported differences in NFB among mung bean cultivars. In case of phosphorous fertilizer application, the gross return and net return were increased with increase in each level of phosphorus up to 46 Kg P_2O_5 ha^{-1}. Application of 46 kg P_2O_5 ha^{-1} recorded highest gross income of 47053.13 ETB and net return of 45003.13 ETB and the lowest was recorded from the control with a gross income of 40280.63 ETB and net return of 40280.63 ETB. This is in line with Dwivedi *et al*. (2018) and Singh (2018) who stated that the gross return increased with increasing level of phosphorous application in mung bean crop. From the study, the interaction of variety Boreda-1 with phosphorous fertilizer rates of 46 Kg P_2O_5 ha^{-1} recorded highest gross income of 50321.25ETB and net return of 47396.25 ETB .While, the lowest was recorded from the interaction of variety NVL-1 with phosphorous fertilizer rates of 0 Kg P_2O_5 ha^{-1} with a gross income of 36303.75ETB and net return of 35428.75 ETB.

Table-8 :Partial budget Analysis of main and interaction effects of variety and phosphorous fertilizer rates for mung bean at Alage,in 2019.

Treatments	Unadjusted yield(Kg ha^{-1})	Adjusted yield(Kg ha^{-1})	GFB(ETB)	TCV(ETB)	Net field benefits
A. Variety					
Boreda-1	1511.88	1360.692	47624.22	875	46749.22
N-26	1423.13	1280.817	44828.6	875	43953.6
NVL-1	1271.25	1144.125	40044.38	875	39169.38
Shoa robit	1333.75	1200.375	42013.13	875	41138.13
B.Phosphorous					
0 Kg P_2O_5 ha^{-1}	1278.75	1150.875	40280.63	0	40280.63
23 Kg P_2O_5 ha^{-1}	1362.50	1226.25	42918.75	1325	41593.75
46 Kg P_2O_5 ha^{-1}	1493.75	1344.375	47053.13	2050	45003.13
69 Kg P_2O_5 ha^{-1}	1405.00	1264.5	44257.5	2775	41482.5
C. Variety*Phosphorous					
Boreda-1*0	1432.50	1289.25	45123.75	875	44248.75
Boreda-1*23	1485.00	1336.5	46777.5	2200	44577.5
Boreda-1*46	1597.50	1437.75	50321.25	2925	47396.25
Boreda-1*69	1532.50	1379.25	48273.75	3650	44623.75
N-26*0	1302.50	1172.25	41028.75	875	40153.75
N-26*23	1412.50	1271.25	44493.75	2200	42293.75
N-26*46	1525.00	1372.5	48037.5	2925	45112.5
N-26*69	1452.50	1307.25	45753.75	3650	42103.75
NVL-1*0	1152.50	1037.25	36303.75	875	35428.75
NVL-1*23	1257.50	1131.75	39611.25	2200	37411.25
NVL-1*46	1390.00	1251	43785	2925	40860
NVL-1* 69	1285.00	1156.5	40477.5	3650	36827.5
Shoa robit*0	1227.50	1104.75	38666.25	875	37791.25
Shoa robit*23	1295.00	1165.5	40792.5	2200	38592.5
Shoa robit*46	1462.50	1316.25	46068.75	2925	43143.75
Shoa robit*69	1350.00	1215	45123.75	3650	41473.75

Table-9: Marginal analysis of main and interaction effects of variety and phosphorous fertilizer rates for mung bean production at Alage,in 2019.

Treatments	GFB(ETB)	TCV(ETB)	Net Field Benefits	MRR(%)
A. Variety				
Boreda-1	47624.22	875	46749.22	-
N-26	44828.6	875	43953.6	-
NVL-1	40044.38	875	39169.38	-
Shoa robit	42013.13	875	41138.13	-
B. Phosphorous				
0 Kg P_2O_5 ha^{-1}	40280.63	0	40280.63	-
23 Kg P_2O_5 ha^{-1}	42918.75	1325	41593.75	99.1
46 Kg P_2O_5 ha^{-1}	47053.13	2050	45003.13	470.25
69 Kg P_2O_5 ha^{-1}	44257.5	2775	41482.5	-
C. Variety*Phosphorous				
Boreda-1*0	45123.75	875	44248.75	-
N-26*0	41028.75	875	40153.75	-
NVL-1*0	36303.75	875	35428.75	-
Shoa robit*0	38666.25	875	37791.25	-
Boreda-1*23	46777.5	2200	44577.5	512.17
N-26*23	44493.75	2200	42293.75	-
NVL-1*23	39611.25	2200	37411.25	-
Shoa robit*23	40792.5	2200	38592.5	-
Boreda-1*46	50321.25	2925	47396.25	1214.31
N-26*46	48037.5	2925	45112.5	-
NVL-1*46	43785	2925	40860	-
Shoa robit*46	46068.75	2925	43143.75	-
Boreda-1*69	48273.75	3650	44623.75	204.14
N-26*69	45753.75	3650	42103.75	-
NVL-1* 69	40477.5	3650	36827.5	-
Shoa robit*69	45123.75	3650	41473.75	-

5. SUMMARY AND CONCLUSION

Mung bean is an important pulse crop in Ethiopia. However, lack of adapted high yielding varieties and poor soil fertility, especially low levels of nitrogen and phosphorus, have been demonstrated to be important constraints for the production of the crop in the country. The producers of mung bean crop also grow the crop in low soil fertility fields rather than using fertilizers essential for good productivity and yield. The field experiment was conducted at Alage ATVET college, central rift valley of Ethiopia to investigate the effect of variety and phosphorous levels on growth, yield and yield components of mung bean. Randomized Complete Block Design (RCBD) with four replications was used to lay the experiment. The treatments consisted factorial combination of four varieties of mung bean(Boreda-1(MH-97 6), Rasa(N-26), NVL-1, and Shoa robit) and four levels of phosphorous(0, 23, 46, and 69 P_2O_5 ha^{-1}) and each arranged in a factorial method. From the present study it is possible to conclude that both variety and phosphorous fertilizer rates affect most of the growth, yield and yield related traits of mung bean crop.

Based on the result of this study, among the four varieties of mung crop boreda-1 is superior in plant height, number of branches $plant^{-1}$, number of pods $plant^{-1}$, number of seeds pod^{-1}, grain yield, and biomass yield than other three varieties. Therefore, this study revealed that variety boreda-1 performed better and gave highest gross benefit of 47624.22 ETB and net benefit of 46749.22 ETB. In case of phosphorous fertilizer rates, application of 46Kg P_2O_5 ha^{-1} exhibited best performance of mung bean growth, yield and yield related traits over the rest of the levels. Grain yield was increased with increasing phosphorous fertilizer rates up to 46 Kg P_2O_5 ha^{-1}

which produced grain yield of 1.5 t ha^{-1}. Also, the highest gross field benefit(47053.13 ETB) and net benefit(45003.13ETB) with acceptable marginal return was obtained from application of 46 kg P_2O_5 ha^{-1}. Whereas most growth, yield and yield components of mung bean were not significantly affected by the interaction effect of variety and different phosphorous fertilizer rates. But the highest gross benefit (50321.25) and net benefit (47396.25) was recorded from the interaction of variety Boreda-1 with phosphorous fertilizer rates of 46 Kg P_2O_5 ha^{-1} . The lowest gross benefit (36303.75) and net benefit(35428.75) was recorded from the interaction of variety NVL-1 with phosphorous fertilizer rates of 0 Kg P_2O_5 ha^{-1} . Thus, based on the findings of the study, variety Boreda-1 with application of 46 kg P_2O_5 ha^{-1} can be used to improve productivity of the mung bean in the study area.However, as this study was based on only one season and one location, it requires further study over the years and location to give conclusive recommendation.

6. REFERENCES

Bouycous, G.H. 1951. A reclamation of hydrometer for making mechanical Analysis of soils. *Agronomy Journal* 43: 434-438.

Abayneh Wubetu,2018.Effects of Intra and Inter-Row Spacing on Yield and Yield Components of Mung Bean (Vigna radiate L.). *Journal of Biology, Agriculture and Healthcare www.iiste.org ISSN 2224-3208 (Paper) ISSN 2225-093X (Online) Vol.8, No.12.*

Abdul-Aziz, A.L., 2013.Contribution of Rhizobium and phosphorus fertilizer to biological nitrogen fixation and grain yield of soybean in the tolon district (Doctoral dissertation, Faculty of Agriculture, Kwame Nkrumah University of Science and Technology).

Achakzai, A.K.K., Habibullah, B.H.S. and Wahid, M.A., 2012. Effect of nitrogen fertilizer on the growth of mungbean [Vigna radiata (L.) Wilczek] grown in Quetta. *Pak. J. Bot*, *44*(3), pp.981-987.

Addisu A.,2007.Species Composition, Distribution, Relative Abundance and Habitat Association of Rodents in Alage (Ziway), Addis Ababa University, Ethiopia.

Ahmad, R.I.A.Z., Ikraam, M., Ullah, E.H.S.A.N. and Mahmood, A.S.I.F., 2003. Influence of different fertilizer levels on the growth and productivity of three mung bean (Vigna radiate L.) cultivars. *Int. J. Agric. Biol*, *5*(3), pp.335-338.

Ali, M.A., Abbas, G., Mohy-ud-Din, Q., Ullah, K., Abbas, G. and Aslam, M., 2010. Response of mungbean (Vigna radiata) to phosphatic fertilizer under arid climate. *J. Anim. Plant Sci*, *20*(2), pp.83-86.

Arain G. N., 2012 . Mungbean Cutivation In Pakistan.

Arebu H., Walelign W. and Moltot Z.,2019. Effects of Deficit Irrigation and Phosphorus Levels on Growth, Yield, Yield Components and Water use Efficiency of Mung Bean (Vigna radiata (l.) Wilczek) at Alage, Central Rift Valley of Ethiopia. Msc thesis of Hawassa University.

Asrate, A., Gurum, F., Alemayehu, F. and Rezene, Y. ,2012. Analysis of Multi-environment Grain Yield Trials in Mung Bean (*Vigna radiate (L.) Wilczek)* Based on GGE Bipot in Southern Ethiopia. *J. Agric. Sci. Tech. 14: 389-398.*

Asim, M., Aslam, M., Hashmi, N.I. and Kisana, N.S., 2006. Mungbean (Vigna radiata) in wheat based cropping system: An option for resource conservation under rainfed ecosystem. *Pakistan Journal of Botany*, *38*(4): p.1197.

Amare Girma , Assaye Demelash And Tuma Ayele,2014.The Response Of Haricot Bean Varieties To Different Rates Of Phosphorus At Arba Minch, Southern Ethiopia . *Arpn Journal Of Agricultural And Biological Science. Vol. 9, No. 10.*

Aziz, A.L.A., Ahiabor, B.D.K., Opoku, A. and Abaidoo, R.C., 2016. Contributions of Rhizobium inoculants and phosphorus fertilizer to biological nitrogen fixation, growth and grain yield of three soybean varieties on a Fluvic Luvisol.

Bandani, M., Mobasser, H.R. and Sirusmehr, A., 2014. Effect of organic fertilizer on length of pod, biological yield and number of seeds per pod in mung bean (Vigna radiata L.). *International research journal of applied and basic sciences*. *Vol, 8 (7): 763-766.*

Bhuiyan, M.M.H., Rahman, M.M., Afroze, F., Sutradhar, G.N.C. and Bhuiyan, M.S.I., 2008. Effect of phosphorus, molybdenum and Rhizobium inoculation on growth and nodulation of mungbean. *J. Soil. Nature*, *2*(2): pp.25-30.

Bouycous, G.H. 1951. A reclamation of hydrometer for making mechanical Analysis of soils. *Agronomy Journal* 43: 434-438.

Bovill, W.D., Huang, C.Y. and McDonald, G.K., 2013. Genetic approaches to enhancing phosphorus-use efficiency (PUE) in crops: challenges and directions. *Crop and Pasture Science*, *64*(3): pp.179-198.

Daniel Manore,and Tefese Altaye ,2018. Effects of Different Level of Phosporous Fertilizer on Yield and Yield Component of Field Pea (Pisum sativum L.) Varieties in Hadiya Zone Duna Area Southren Ethiopia .*Asian Journal of Plant Science and Research*, 8(2):8-14.

DAS , K.,2017. Varietal Performance Of Bush Type French Bean Varieties (Phaseolus Vulgaris L.) For Growth, Fresh Pod Yield And Quality.

DAFF ,2010.mung bean production guidelines.

Dharwe, D.S., Dixit, H.C., Dotaniya, C.K., Doutaniya, S.M.R. and Jamara, P., 2018. Influences of phosphorus and sulphur on yield attributes of summer green gram (Vigna radiata L.). *Journal of Pharmacognosy and Phytochemistry*, *7*(2): pp.147-149.

Dwivedi, G., Mishra, U.S. and Pathak, R.K., 2018. Study of different varieties and phosphorus levels on yield attributes and economics of green gram (Vigna radiata L.). *Journal of Pharmacognosy and Phytochemistry*, *7*(6): pp. 84-88.

Ethiopia Commodity Exchange,2009. http://www.ecx.com.et/commodities.aspx#block.

EPP (Ethiopian Pulses Profile),2004. "Ethiopian export promotion agency, product development & market research directorate, Addis Ababa, Ethiopia".

Erana Kebede ,2020. Grain legumes production and productivity in Ethiopian smallholder agricultural system, contribution to livelihoods and the way forward, Cogent Food & Agriculture, 6:1.

Fantaye Belay, Hintsa Meresa, Shambel Syum and Atsbha Gebresilasie,2019. Evaluation of improved mung bean (Vigna radiata L.) varieties for yield in the moisture stress conditions of Abergelle Areas, Northern Ethiopia.*Journal of Agricultural Science and Practice Volume 4(4), pages 139-143.*

Fanuel Laekemariam and Walelign Worku,2013. Growth, Light Interception, Radiation Use Efficiency And Productivity Of Mungbean (*Vigna Radiata (L.) Wilczek*) (Fabaceae) Cultivars As Influenced By Sowing Date.

FAO ,2010. Special Report Fao/Wfp Crop and Food Security Assessment Mission to Ethiopia.

FAO, 2008. Efficiency of soil and fertilizer phosphorus use Reconciling changing concepts of soil phosphorus behaviour with agronomic information.

FAO,2012. Using residual soil moisture after monsoon rice crop for Mung Bean production in drought prone areas, Bangladesh.

Fertilizer Association of Ireland in association with Teagasc,2019. The Efficient Use of Phosphorus in Agricultural Soils.

Gautam, V.K., 2017. Effect of phosphorus and sulphur levels on growth and yield of greengram (vigna radiata l. wilczek) underguava (psidium guajava) based agrihorti system (Doctoral dissertation, Department of Agronomy, Institute of Agricultural Sciences, BHU. Varanasi).

Gebre-Egziabher Murut, Hadush Tsehaye and Fetien Abay,2014. Agronomic performance of some haricot bean varieties (haseolus vulgaris L.) with and without phosphorus fertilizer under irrigated and rain fed conditions in the Tigray and Afar regional states, northern Ethiopia. *Momona Ethiopian Journal Of Science (Mejs), Volume 6(2):95-109*.

Geletu T. and Mekonnen F.,2018. The Effect of Bio and Inorganic Fertilizer on Yield, Nutrient Uptake and Economics of Mungbean (Vigna Radiata L. Wilczek) Varieties in Ethiopia. *Open Access Journal of Agricultural Research*.

Gifole Gidago, Sheleme Beyene , Walelign Worku,2011. The Response of Haricot Bean (Phaseolus vulgaris L.) to Phosphorus Application on Ultisols at Areka, Southern Ethiopia. *Journal of Biology, Agriculture and Healthcare, Vol 1: No.3.*

Gupta, A. and Sahu, P.K., 2017. Phosphorus Nutrition of Plants: A Microbial Perspective. *MOJ Eco Environ Sci*, *2*(6): *p.00043.*

Habte Umata,2018. Evaluation of Adaptability of Mung Bean Varieties in Moisture Stress of Eastern Harerghe Zone. *Agricultural Research & Technology: Open Access Journal.*

Hamza, B.A., Chowdhury, M.A.K., Rob, M.M., Miah, I.M., Habiba, U. and Rahman, M.Z., 2016. Growth and Yield Response of Mungbean as Influenced by Phosphorus and Boron Application. *Journal of Experimental Agriculture International*, 11(3): pp.1-7.

Havlin, L., Beaton, L., Tisdale, L. and Nelson, L. 1999. Soil fertility and fertilizers*; an introduction to nutrient management. 6th ed*. Pearson education Inc. New Delhi, India. pp. 90-405.

Hussain, F., Malik, A.U., Haji, M.A. and Malghani, A.L., 2011. Growth and yield response of two cultivars of mungbean (Vigna radiata L.) to different potassium levels. *J. Anim. Plant Sci*, 21(3): Page: 622-625.

Hossain, M.M., Mahbub, M.M. and Shirazy, B.J., 2016. Growth and yield performance of mungbean varieties in summer cultivation. *Scientia Agriculturae, 16*(3), pp.79-82.

Hossen, M.M., Hussain, A.I., Al Zabir, A., Biswas, M.J.H. and Islam, M.R., 2015. Effect of nitrogenous fertilizer on yield of mungbean [Vignaradiata (L.) Wilczek] in Patuakhali district of Bangladesh. *Asian Journal of Medical and Biological Research*, *1*(3), pp.508-517.

Imran, Khan, A.A., Inam, I. and Ahmad, F., 2016. Yield and yield attributes of Mungbean (Vigna radiata L.) cultivars as affected by phosphorous levels under different tillage systems. *Cogent Food & Agriculture*, *2*(1): p.1151982.

Imran, Zada H., Naveed S., Khattak I. And Ahmad S., 2016. Variable Rates Of Phosphorous Application Influenced Phenological Traits Of Green Gram (Vignaradiata L.). *Open Access Journal Of Agricultural Research. Volume 1 Issue 3.*

Ismail, 1993. A critical analysis of" harvest index". *Qatar Univ. Sci. J. 13(2): 253- 263*

Itefa Degefa ,2016. General Characteristics and Genetic Improvement Status of Mung bean (*Vigna radiata L.*) in Ethiopia: Review Article. *International Journal of Agriculture Innovations and Research Volume 5, Issue 2.*

Itefa Degefa, Yohannes Petros & Mebeaselassie Andargie(2014). Genetic Variability, Heritability and Genetic Advance in Mungbean (Vigna radiata L. Wilczek) Accessions. Plant Science Today, 1(2): 94-98.

Jackson, C.M., 2014. *Effects Of Phosphorus And Cassava-Soybean Intercrop On Soybean Nodulation And Cassava Yield In South-Kivu, Democratic Republic Of Congo* (Doctoral dissertation, Kenyatta University).

Jaidee, R., Polthanee, A. and Saenjan, P., 2012. Growth and yield of soybean cultivars as affected by ground water levels and phosphorus rates grown under greenhouse and field conditions. *Australian Journal of Crop Science*, *6*(1), p.81.

Kabir, M.H. and Sarkar, M.A.R., 2008. Seed yield of mungbean as affected by variety and plant spacing in Kharif-I season. *Journal of the Bangladesh Agricultural University*, *6*(452-2016-35516).

Karanja, D., 2016. Pulses crops grown in Ethiopia, Kenya and United Republic of Tanzania for local and Export Market. *International Trade Centre, Eastern Africa Grain Council*.

Karim, A., Qasim, M., Din, M., u Din, T., Imran, M. and Gurmani, Z.A., 2014. Effect Of Phosphorous On The Yield And Yield Components Of Mungbean At Marc, Juglote, Gilgit-Baltistan, Pakistan.*Life Sciences International Journal*, *8*, pp.2936-2939.

Khan, A., Anwer, S. and Afridi, M.Z., 2015. Response Of Mungbean (Vigna Radiata L.) Cultivars To Various Levels Of Phosphorous Application In Agroclimatic Condition Of Peshawar.

Khan, F.U., Khan, M., Hassan, M. and Gul, R., 2017. Genotypic Differences among Mung Bean (Vigna radiata L.) Genotypes for Yield and Associated Traits. *International Journal of Applied Agricultural Sciences*, *3*(2), p.47.

Khan, M.A., Aslam, M. and Tariq-Sultan, M.I., 2002. Response of phosphorus application on growth and yield of inoculated and un-inoculated mungbean (Vigna radiata). *Int J Agric Biol*, *4*(4):pp.523-24.

Khan, M.A., Baloch, M.S., Taj, I. and Gandapur, I., 1999. Effect of phosphorus on growth and yield of mungbean. *Pak. J. Biol. Sci*, *2*(1), pp.667-669.

Khan, M., Salman, M., Singh, V.P. and Kumar, A., 2017. Studies on Effect of Phosphorous Levels on Growth and Yield of Kharif Mungbean (Vigna radiataL. wilczek). *International Journal of Pure & Applied Bioscience*, *5*(4), pp.800-808.

Kidane Georgis and Bedru Beshir,2000. Cereals and Grain Legumes for Semi-Arid Areas of Ethiopia.

Kumar, D., Singh, R.K., Pareek, B., Yadav, R.S., Anuradha, R.G.M.S. and Dubey, S.K., 2017. Response of Different Sources of Phosphorus on Growth, Nodulation and Yield on Greengram (Vigna radiata L.). *Int. J. Pure App. Biosci*, *5*(6), pp.201-207.

Landon, J.R. 1991. *Booker Tropical Soil Manual:* A hand book for soil survey and Agricultural Land Evaluation in the Tropics and Subtropics. Long man Scientific and Technical, Essex, New York. USA. 474p.

Madhu, G., 2013. Response of mungbean (Vigna radiata L. Wilczek) genotypes to dates of sowing and foliar nutrition in kharif season (Doctoral dissertation, UAS, Dharwad).

Mbeyagala, K.E., Amayo, R., Obuo, J.P., Pandey, A.K., War, A.R. and Nair, R.M., 2017. A manual for mungbean (greengram) production in Uganda. *Natl. Agric. Res Org.(NARO)*, *32*.

McKenzie, R.H. and Middleton, A., 2013. Phosphorus Fertilizer Application in Crop Production. Practical information for Alberta's Agriculture industry.

Meseret Turuko, Amin Mohammed,2014. Effect of Different Phosphorus Fertilizer Rates on Growth, Dry Matter Yield and Yield Components of Common Bean (Phaseolus vulgaris L.) . *World Journal of Agricultural Research, Vol. 2, No. 3, 88-92.*

Mesfin Bebiso,2017. A Review Of Challenges, Opportunities And Management Practices Of Mung Bean(*Vigna Radiata L.,Wilczek*) In Ethiopia. International Journal Of Current Research Vol. 9, Issue, 01, Pp.45644-45647.

Mesfin Kassa , Belay Yebo Abera Habte,2014. The Response of Haricot Bean (Phaseolus Vulgaris L) Varieties to Phosphorus Levels on Nitosols at Wolaita Zone, Ethiopia. *Journal of Biology, Agriculture and Healthcare Vol.4, No.17.*

Minh, N.P., 2014. Different factors affecting to mung bean (Phaseolus aureus) tofu production. *Int. J. Multi. Res. Dev*, *1*(4), pp.105-110.

Mohamed, M.H. and El Kramany, M.F., 2005. Salinity tolerance of some mungbean varieties. *J. of Applied Sci. Res*, *1*(10), pp.78-84

MoANR,2016. Plant Variety Release, Protection and Seed Quality Control Directorate.Crop Variety Register Issue No. 19.

Mondal, M.M.A., Puteh, A.B., Malek, M.A., Ismail, M.R., Rafii, M.Y. and Latif, M.A., 2012. Seed yield of mungbean (Vigna radiata (L.) Wilczek) in relation to growth and developmental aspects. *The Scientific World Journal*, *2012*.

Muchira, B., Kamau, P. and Mushimiyimana, D.,2018. Effects Of Spacing And Fertilization On Growth And Grain Yields Of Mung Beans (Vignaradiata (L) Wilckzeck) In Dry Areas Of Subukia, Kenya.

Muralidharudu, Y., Murthy, I.Y.L.N., Reddy, K.P.C., Reddy, B.N. and Chandranath, H.T., 2003. Response Of Sunflower (Helianthus Annuus L.) To Phosphorus Application In Vertisols/Reacción De Girasol (Helianthus Annuus L.) *Helia*, *26*(39), pp.147-154.

Nikfarjam, S.G. and Aminpanah, H., 2015. Effects of phosphorus fertilization and Pseudomonas fluorescens strain on the growth and yield of faba bean (Vicia faba L.). *Idesia*, *33*(4), pp.15-21.

Rahman, M.M., Adan, M.J., Chowdhury, M.S.N., Ali, M.S. and Mahabub, T.S., 2015. Effects of Phosphorus and Zinc on the Growth and Yield of Mungbean (BARI mug 6). *International Journal of Scientific and Research Publications*, *5*(2), pp.1-4.

Rani, M., Prakash, V. and Khan, K., 2016. Response of mungbean [Vigna radiata (L.) Wilczek] to phosphorus, sulphur and PSB during summer season. *Agricultural Science Digest-A Research Journal*, *36*(2), pp.146-148.

Rasul, F., Cheema, M.A., Sattar, A., Saleem, M.F. and Wahid, M.A., 2012. Evaluating the performance of three mungbean varieties grown under varying inter-row spacing. *J. Anim. Plant Sci*, *22*(4): pp.1030-1035.

Rehman, A., Khalil, S.K., Nigar, S., Rehman, S., Haq, I., Akhtar, S., Khan, A.Z. and Shah, S.R., 2009. Phenology, plant height and yield of mungbean varieties in response to planting date. *Sarhad J. Agric*, *25*(2): pp.147-151.

Rekha, K., Pavaya, R.P., Neha, C. and Patel, S., 2018. Effect of FYM, Phosphorus and PSB on Growth, Yield and Quality of Greengram [Vigna radiata (L.) Wilckzek] on Loamy Sand. *International Journal of Bio-resource and Stress Management*, *9*(2): pp.220-223.

Robu, T., Brezeanu, C., Brezeanu, P.M. and Ambarus, S., 2014. Assessment of mung bean yield potential production in the north eastern region of Romania. *Scientific Papers-Series A Agronomy*, *57*: pp.310-315.

Sehrawat, N., Jaiwal, P.K., Yadav, M., Bhat, K.V. and Sairam, R.K., 2013. Salinity stress restraining mungbean (Vigna radiata (L.) Wilczek) production: gateway for genetic improvement. *International Journal of Agriculture and Crop Sciences*, *6*(9): p.505.

Serawat, A., Sharma, Y., Serawat, M., Kapoor, A. and Jakhar, R.K., 2018. Effect of Phosphorus and Sulphur on Growth attributes and Yield of Mungbean (Vigna radiate L.) in Sandy Soils of Hyper Arid Western Plains of Rajasthan. *Int. J. Curr. Microbiol. App. Sci*, *7*(08): pp.2674-2683.

Singh, P., Yadav, K.K., Fatteh Singh Meena, B.S. and Singh, R., 2017. Effect Of Phosphorus And Sulphur On Yield Attributes, Yield And Nutrient Uptake Of Mungbean (Vigna Radiata L.) In Central Plain Zone Of Punjab, India. *Plant Archives*, *17*(2): pp.1756-1760.

Singh, R., Singh, P., Singh, P. and Yadav, R.A., 2018. Effect of phosphorus and PSB on yield attributes, quality and economics of summer greengram (Vigna radiata L.). *Journal of Pharmacognosy and Phytochemistry*, *7*(2): pp.404-408.

Sipai, A.H., Jat, J.R. and Rathore, B.S., 2016. Effect Of Phosphorus, Sulphur and biofertilizer on growth, yield and nodulation in mungbean on loamy sand soils of Kutch. *Crop Research*, *51*(1).

Tajer A. ,2016.What's the function of Phosphorus (P) in plants?

Takele Zike, Tolera Abera, and Ibrahim Hamza, 2017. Advances in Crop Science and Technology.

Tarikua Fikadu Tekle, 2017. Response Of Mungbean [Vigna Radiata (L.)Wilczek] Varieties To Plant Spacing Under Irrigation At Gewane, Afar Region, Northeastern Ethiopia.

Teame Gereziher, Ephrem Seid, Lemma Diriba, Getachew Bisrat ,2017. Adaptation Study Of Mung Bean (*vigna radiate L.*) Varieties In Raya Valley, Northern Ethiopia.

Tensay Ayalew Asegie,2015.Mungbean (Vigna radiata (L.) Wilczek) (Fabaceae) Landrace Diversity in Ethiopia.

Uddin, F.M.J., Sarkar, M.A.R. and Mamun, A.A., 2010. Effect of variety, date of planting and level of phosphorus on shoot dry matter and yield of mungbean. *Journal Agroforestry Environment*, *4*(2):pp.121-124.

Ullah, A., Ali, A., Waseem, M. and Nadeem, M.A., 2010. Response of Two Mungbean Cultivars with Different Phosphorus Levels Under Faisalabad Condition. *International Journal of Applied , Agricultural Research 5*(5): pp.621-628.

Verma, G., Kumawat, N. and Morya, J., 2017. Nutrient Management in Mungbean [Vigna radiata (L.) Wilczek] for higher production and productivity under semi-arid tract of central India. *Int. J. Curr. Microbiol. App. Sci*, *6*(7): pp.488-493.

Walkley, A. and Black, C.A. 1934. An experimentation of Degtjareff method for determining soil organic matter and the proposed modification of the chromicacid titration method. *Soil Science* 37: 29-38.

Wedajo, G., 2015. Adaptation study of improved mung bean (Vigna radiata L) varieties at Alduba, south Omo Ethiopia. *Research Journal of Agriculture and Environmental Management*, *4*(8), pp.339-342.

Yadav V. K.,2017. Effect of Phosphorus and Bio- inoculants on Soil Fertility and Yield of Summer Mungbean [Vigna radiata (L.) Wilczek]. Department of Agricultural Chemistry & Soil Science Rajasthan College of Agriculture.

Yehuala Kassa, Daneil Admasu, Abiro Tigabe, Amsalu Abie and Dejene Mamo,2018. Participatory on farm evaluation of improved mungbean technologies in the low land areas of North Shewa Zone Amhara Region, Ethiopia. *Journal of Agricultural Extension and Rural Development.*

Yin, Z., Guo, W., Xiao, H., Liang, J., Hao, X., Dong, N., Leng, T., Wang, Y., Wang, Q. and Yin, F., 2018. Nitrogen, phosphorus, and potassium fertilization to achieve expected yield and improve yield components of mung bean. *PloS one*, *13*(10).

Yumnam, T., Luikham, E. and Singh, A.H., 2018. Influence of Phosphorus on Growth and Yield of Promising Varieties of Lentil (Lens culinaris L. Medik). *Int. J. Curr. Microbiol. App. Sci*, *7*(8), pp.162-170.

Zahan, T., Ali, M.S., Rahman, M.M., Begum, M. and Bell, R.W., 2016. Effect of variety and seed rate of mungbean on weed suppression and yield under strip tillage system. *Journal of the Bangladesh Agricultural University*, *14*(1), pp.49-56.

7. APPENDIXES

Appendix table 1: Mean squares of days to flowering and maturity of mung bean crop at Alage during belg seasons of 2019

Source of Variation	D F	Mean squares	
		Crop parameters	
		DTF	DTM
V	3	17.94*	57.84***
P	3	36.6***	54.49***
R	3	2.27ns	0.27ns
V*P	9	4.92ns	0.72ns
Error	45	4.8	4.45

Where, DF = degree of freedom, DTF= days to flowerings, DTM = days to maturity, V = variety, P = phosphorous, R = replications, V*P = interaction effects of variety with phosphorous, * = Significant at 0.05, ** = Significant at 0.01, *** = Significant at 0.001, ns = not significant at 0.05 level of probability.

Appendix table 2: Mean squares of nodule number, nodule dry weight, and root dry weight plant^{-1} at Alage during belg seasons of 2019

Source of Variation	D F	Mean squares		
		Crop parameters		
		RDW	NN	NDW
V	3	67.09**	0.03***	0.49*
P	3	72.52**	0.02***	0.74**
R	3	32.04ns	0.001ns	0.32ns
V*P	9	8.12 ns	0.008 ***	0.08ns
Error	45	12.03	0.0008	0.12

Where, DF = degree of freedom, NN = nodule number plant^{-1}, NDW = nodule dry weight, RDW = Root dry weight, V = variety, P = phosphorous, R = replications, V*P = interaction effects of variety with phosphorous, * = Significant at 0.05, ** = Significant at 0.01, *** = Significant at 0.001, ns = not significant at 0.05 level of probability.

Appendix table-3: Mean squares of plant height, number of branches plant^{-1} and shoot dry weight at Alage, during belg seasons of 2019

Source of Variation	D F	Mean squares		
		Crop parameters		
		PH	NB	SDW
V	3	238.37***	6.36***	156.56***
P	3	377.49***	14.34***	173.58***
R	3	38.28ns	0.19ns	13.20ns
V*P	9	3.86ns	0.32*	3.11ns
Error	45	23.9	0.13	5.78

Where, DF = degree of freedom, PH = plant height, NB = number of branches plant^{-1}, V = variety, P = phosphorous, R = replications, V*P = interaction effects of variety with phosphorous, * = Significant at 0.05, ** = Significant at 0.01, ***= Significant at 0.001, ns = not significant at 0.05 level of probability.

Appendix table 4: Mean squares of number of pods plant^{-1}, number of seeds pod^{-1} and grain yield at Alage during belg seasons of 2019

Source of Variation	D F	Mean square		
Crop parameters				
		NPPP	NSPP	GY
V	3	628.53***	0.85*	176976.02***
P	3	110.28***	1.76***	129011.27***
R	3	7.06ns	0.21ns	4360.6ns
V*P	9	14.74**	0.14ns	1272.57ns
Error	45	3.93	0.22	12170.62

Where, DF = degree of freedom, NPPP = number of pods plant^{-1}, NSPP = number of seeds pod^{-1}, GY = grain yield ha^{-1}, V = variety, P = phosphorous, R = replications, V*P = interaction effects of variety with phosphorous, * = Significant at 0.05, ** = Significant at 0.01, *** = Significant at 0.001, ns = not significant at 0.05 level of probability.

Appendix table 5: Mean squares of biological yield yield, harvest index and hundred seed weight at Alage during belg seasons of 2019

Source of Variation	D F	Mean square		
Crop parameters				
		BY	HI	HSW
V	3	408202.56***	86.23***	0.49*
P	3	667702.14***	3.71 ns	0.78***
R	3	41681.72ns	1.83ns	0.32ns
V*P	9	12954.97ns	0.51ns	0.085ns
Error	45	54126.97	9.24	0.12

Where, DF = degree of freedom, GY= grain yield, HI = harvest index, HSW = hundred seed weight, V = variety, P = phosphorous, R = replications, V*P = interaction effects of variety with phosphorous, ** = Significant at 0.01, *** = Significant at 0.001, ns = not significant at 0.05 level of probability.

Appendix table-6: linear correlation analysis among nodule, growth, and yield parameters of mung bean.

variables	DTF	DTM	NN	NDW	RDW	PH	NB	SDW	NP	NS	GY	BIO	HI	HSW
DTF	1													
DTM	0.37**	1.00												
NN	-0.48***	-0.39**	1.00											
NDW	-0.55***	-0.53***	0.49***	1.00										
RDW	-0.28*	-0.34***	0.62***	0.35**	1.00									
PH	-0.08ns	-0.01ns	-0.06ns	0.00ns	0.10ns	1.00								
NB	-0.15ns	-0.15ns	0.11ns	0.04ns	0.16ns	0.58***	1.00							
SDW	-0.22ns	0.03ns	-0.01ns	0.06ns	0.08ns	0.71***	0.77***	1.00						
NP	-0.12ns	-0.21ns	0.13ns	0.00ns	0.13ns	0.31*	0.44***	0.25***	1.00					
NS	-0.24ns	-0.30*	0.13ns	0.17ns	0.24ns	0.30*	0.45***	0.33**	0.50***	1.00				
GY	-0.24ns	-0.15ns	0.18ns	0.10ns	0.10ns	0.55***	0.52***	0.50***	0.64***	0.37**	1.00			
BIO	-0.13ns	0.00ns	0.02ns	0.10ns	0.07ns	0.85***	0.59***	0.70***	0.28*	0.32**	0.49***	1.00		
HI	-0.15ns	-0.18ns	0.18ns	0.02ns	0.04ns	-0.06ns	0.11ns	0.01ns	0.51***	0.17ns	0.74***	-0.23ns	1.00	
HSW	-0.38**	-0.36**	0.70***	0.43***	0.36**	0.00ns	0.20ns	-0.04ns	0.16ns	0.33**	0.13ns	0.00ns	0.13ns	1.00

Appendix Table-7.Long-term Climatic Data of Alage (2006-2019 G.C.) for Reference evapotranspiration (ETo) based on Penman-Monteith method

Summary of meteorological data (2006-2019) of Alage								
Months	Min. Temp (°C)	Max. Temp (°C)	Humidity (%)	Wind (km/day)	Sun (hours)	Rain (mm)	ETo* (mm/day)	Rad Mj/m2/day
January	7.9	29.07	37.09	71.79	7.38	7.5	3.85	19.88
February	11	30.57	37.01	67.046	7.95	34.7	3.93	19.54
March	11.95	31.054	53.31	68.07	7.87	79.2	4.56	21.49
April	14.83	29	50.89	69.36	7.83	86.4	3.98	19.8
May	11.9	28.6	74	78	8.9	90.6	4.38	22.5
June	12.3	28	75	95	8.1	107.5	4.11	20.9
July	12.8	25.5	78	52	6.3	139	3.46	18.4
August	12.6	26	77	35	6.7	123.7	3.6	19.5
September	12.5	27	77	69	7.1	103.5	3.83	20.2
October	10.5	31.9	71	69	9.2	20.8	4.53	22.7
November	9.2	29.1	58	86	10.2	8.4	4.39	23
December	8.89	28.08	37.2	79.6	8.1	2.6	3.84	19.42

Data source: C/CROPWAT/CLIMWAT/ ALAGE METROLOGY STATION Longitude 38^0 56’ E, Latitude 7^0 65' N Altitude of 1600 m. a. s. l.

8.BIOGRAPHICAL SKETCH

The author, Habtam Tilahun, was born on 14 January 1991 from her father Tilahun Asratie and her mother Tibka Demssie, in Mertule Mariam Wereda , East Gojam Zone, Amhara Regional State. When she reached school age, she enrolled at Bakelaye Primary School to attend elementary from 2000-2007. She then joined Abrha Woatsibeha secondary and Preparatory school(2008-2011).After successfully passing the Ethiopian School Leaving Certificate Examination, she joined Debre Markos University in 2012 and graduated with the degree of Bachelor of Science in Plant Sciences in 2014. Upon graduation, she was employed by Alage agricultural technical vocational education training which is under agricultural technical vocational training of ministry of agriculture Ethiopia from 2015 to date. She joined the School of Graduate Studies at Hawssa University in 2017 to pursue a study leading to the Degree of Master of Science in Agronomy.

Appendix 8: Time of sowing of mung bean crop seeds

Appendix-9: Seedling stages of mung bean crop at 8 days after sowing of the experiment

Appendix-10: Irrigation of mung bean crop at experimental field

Appendix-11: Thinning of mung bean crop at experimental field

Appendix-12: Nodule parameters data collection for mung bean crop.

Appendix -13: nodules of mung bean crop at the time of nodule data collection

Appendix -14: Pods of mung bean crop at the experimental field

Appendix -15: Mung bean crop starts to maturity at fields of the experiment

Appendix -15: Mung bean crop starts to maturity at fields of the experiment