RESPONSE OF SOYBEAN (*Glycine max (*L.*)*Merrill) TO PLANT POPULATION AND NP FERTILIZER IN KERSA WOREDA OF JIMMA ZONE, SOUTH WESTERN ETHIOPIA

M.Sc. THESIS RESEARCH

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NOVEMBER 2016

JIMMA, ETHIOPIA

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M.SC. THESIS RESEARCH

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HABTAMU DERIBE BIKILA

NOVEMBER 2016

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DEDICATION

I dedicate this Thesis manuscript to my father Ato DeribeBikila, mam Mrs BeletechKebede who passed away without seeing my success today and to my youngest brother Tolossa Deribe for their responsibility in nurturing my life and constant encouragements to successfully complete my post-graduate study.

STATEMENT OF THE AUTHUR

First I declare that this thesis is my work and that all sources of the materials used for this thesis have been duly acknowledged. This thesis has been submitted to in partial fulfillment of the requirements for M.Sc. degree at Jimma University, College of Agriculture and Veterinary Medicine and deposited at the University Library to be made available to borrowers under the 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.

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BIOGRAPHOCAL SKITCH

Habtamu Deribe Bikila was born on July 10, 1988 in SNNPRS Kafa Zone, Gesha woreda Yeeri Kichit kebele. He attended his education at Idiget Tesfa primary and secondary School, at Shishinda High School and Masha preparatory school from 1998 to 2007, respectively. After successfully passing the Ethiopian School Leaving Certificate Examination, he joined Mizan-Teppi University, College of Agriculture and Natural Resource in 2008 academic year and graduated with B.Sc. degree in Agriculture (Horticulture) in 2010. After graduation, he was employed by the SNNPR Bureau of Agriculture as an agronomist at Gesha District (Kafa Zone). Further he was employed by Seka Agro Processing Private Limited Company and totally served for four years. In September 2014, he joined the graduate studies program of the Jimma University College of Agriculture and Veterinary Medicine to pursue his M.Sc. degree in Agriculture (Agronomy).

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LIST OF ABBREVIATIONS

ANOVA	Analysis of Variance
BoA	Bearu of Agriculture
CACC	Central Agricultural Census Commission
CSA	Central Statistical Agency
DAP	Diammonium Phosphate
EARO	Ethiopian Agricultural Research Organization
FAO	Food and Agricultural Organization
FAOSTAT	Food and Agricultural Organization Statistics
IFAD	International Fund for Agricultural Development
IITA	International Institute of Tropical Agriculture
IPCC	International Panel of Climate Change
JARC	Jimma Agricultural Research Center
JUCAVM	Jimma University College of Agricultural and Veterinary Medicine
LSD	List significance difference
MoA	Ministry of Agriculture
M AF S	Ministry of Agriculture and Food Security
Masl	Meter above sea level
N	Nitrogen
NGO	Non-Governmental Organization
P	Phosphorous
SAS	Statically Analysis System
SNNPR	South Nations, Nationalities and Peoples' Region
UREA	Nitrogen fertilizer with the chemical formula $(NH_2)_2CO$
USDA	United State Department of Agriculture

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ABSTRACT

*Soybean (Glycine max (*L.*)* Merrill*) is a leading oil and protein crop of the world and can be used as a source of high quality edible oil, protein, and livestock feed.Declining soil fertility status and poor agronomic practices, includingminimum use of inorganic fertilizers and inappropriate plant population are the major reasons for the lower yield of soybean. A field experiment was carried out to determine the response of soybean to plant population and NP fertilizer in Kersa woreda of Jimma zone, south western Ethiopia during the 2015/2016 cropping season. The study site is situated at an altitude of 1740 masl and the texture of the soil is clay. Each four levels of NP fertilizer (23/23, 23/46, 46/46 and 69/69 kg/ha) and plant population (166,667, 200000, 333,333 and 400,000 plants/ha) were laid out in a factorial experiment in randomized complete block design with three replications. The released and commonly used soybean variety Clark–63K was used for the study. Data on phenology, yield and yield components were collected and statistically analyzed to identify the best treatments. The analysis of variance showed that the interaction of plant population and NP fertilizer wassignificant for number of pods per plant, pod length, number of nodules per plant, hundred seed weight, total biomass yield and grain yield. Whereas, plant population had significant influences on days to 50% flowering, days to 50% maturity, number of branches per plant, number of nodules per plant, plant height, total leaf area, number of pods per plant, number of seed per pod, hundred seed weight, total biomass yield and grain yield per plat.Likewise, the main effects of NP fertilizer was significant for number of pods per plant, number of branches per plant, number of leaves per plant, total leaf area, plant height, days to maturity, leaf fresh and dry weights, pod length, hundred seed weight, gran yield and harvest index. The highest grain and biomass yields of 1960 and 5491.7 kg/ha were recorded at 400,000plant/ha plant population and 23/46kg/ha NP fertilizer. Moreover, the partial budget analysis also revealed that the highest net benefit and marginal rate of return (24063.6birr/ ha and 276%) and (25456.4 birr/ha and 623%) were obtained from 400,000plant/ha plant population and 23/46kg/ha NP fertilizer. However, to generate more reliable information and technology, further studies need to be conducted by taking into consideration other factors, including different locations, varieties, fertilizers, plant population, cropping systems and growing seasons in Jimma zone and other suitable areas in southwestern Ethiopia.*

Key words: NP fertilizer, plant nutrients, plant population, soil fertility management

1. INTRODUCTION

Soybean (*Glycine max* (L.) Merrill) is an important global legume crop that grows in the tropical, subtropical and temperate climates. Like peas, beans, lentils and peanuts, it belongs to the large botanical family, Leguminosae, in the subfamily Papilionideae. It has 40 chromosomes (2n = 2x = 40) and is a self-fertile species with less than 1% out-crossing (Shurtleff and Aoyagi, 2007).It is the leading oil and protein crop of the world, which is used as a source of high quality edible oil, protein and livestock feed (Rajcan*et al.,* 2005). It has a potential to nourish humans worldwide in the near and distant future (Hartman *et al.,* 2011). The balanced combination of protein, fat and carbohydrates in soybean products could serve as a valuable food, feed and bio-feed stocks of crops (Gardner and Pyne, 2003). Many other products with a soybean basis are also directly used for human consumption (soymilk, soy yogurt, snacks, soya sauce, protein extract and concentrates, etc.,) (Collombet, 2013). It improves soil fertility by fixing atmospheric nitrogen and its oil is also increasingly being used for biodiesel (Acikgoz*et al.,* 2009).

Global production has been on the rise, its estimated demand of about 300 million tons exceeds the current supply by over 40 million tons (FAOSTAT, 2010).With current yields estimated at less than 30% of the actual potential land, only about 7% of favorable land is allocated to soybeans, Sub-Saharan Africa presents a great opportunity for closing this global demand-supply gap (Hartman *et al.,* 2011).Soybean protein provides all eight amino acids in the amount needed for human health; hence, it is the best source of protein and oil and truly claims the title of the meat/oil on plants (Ali, 2010). The different climatic zones found in Africa include tropical wet, tropical summer rainfall, semiarid, arid, highland and Mediterranean (Newman *et al.,* 2007). It offers several advantages in sustainable cropping systems (Sinclair and Vadez, 2012), including an ability to fix atmospheric nitrogen (N_2) via symbiotic N_2fixation. In particular, soybeans nutritional value and its high N_2 fixing potential could result in playing a major role in future cropping systems of Africa (IITA, 2009). Soybean production in this area is projected to grow from about 1.5 million tons in 2010 to about 2 million tons in 2020, representing a growth rate of 2.3% per annum to meet the predicted demand (Abate *et al*., 2012).

The introduction of soybean crop to Ethiopia dated back to 1950s with the objective of supplementing the diet of Ethiopians, especially during long periods of partial fasting (Asrat, 1965). In 2014/15 cropping season, the total area nationally covered by soybean crop was about 35,259.76 ha and the total production of 721,837.45 quintal with a productivity of 20.47 qt/ha (CSA, 2015). Some of the constraints shown by studies (Shumba-Mnyulwa, 1996) carried out on smallholder soybean production. Soil pH, generally at values less than 5.5 to 6.0, can drastically affect rhizobia infection, root growth and legume productivity (Havlin*et al*., 2005). Plant population is an important component of yield in soybean and hence, it is important to determine the optimum plant population density for different areas, since the areas have different potential for soybean growth, with some areas having the capacity to support high plant density without a compromise in yield (Masuda and Goldsmith, 2009). Studies by Taylor (1980) have shown that soybean respond differently to different environmental conditions and these environmental differences would lead to differences in yield between seasons. Rainfall and soil moisture must be optimized when considering effects of plant density on soybean yield (Bertram and Pedersen, 2004).

Higher plant densities compared to lower plant density have consistently produced higher seed yield**s** in Northern USA where indeterminate early maturing varieties are used (Ball *et al*., 2000). Increased seed rate influenced yield to a point, while yield will eventually reach a maximum at which addition of more seed will do nothing to increase yield (Ball *et al*., 2000). The study done in Zimbabwe has revealed that soybean does well at 300 000 plants/ha in high potential areas and 150000 plants/ha in low potential areas (Whingwiri, 1986). A previous study conducted in this study area but with different varieties (Worku and Astatkie, 2011) reported an increase in seed yield per unit area as row spacing (RS) decreased, but it did not identify optimum plant density for high yield, nodulation and weed control.

In spite of many biotic and a biotic factors contribute to the low yield of soybean which includes, nitrogen and phosphorus are the major factors that significantly reduce the production and productivity of soybean(Kamara *et al*., 2007; Tahir *et al*., 2009). The low availability of phosphorus nutrition in soils has become the limiting factor for plant and root growth (Zafar*et al*., 2013). Legume plants that depend on biological N_2 fixation require more P, since, the reduction of atmospheric N_2 by the nitrogenous system is a very energy-consuming process and more P and other nutrients are needed for symbiotic N fixation than for general plant metabolism

(Israel, 1987). Nitrogen is the most important nutrient for crop production and its deficiency occurs in most countries of the world (Tahir *et al*., 2009). Best timing for N top-dressing during reproduction is at the flowering stage, which increased seed yield by 21%, compared to the treatment without N top dressing (Gan*et al.*, 2003). Currently, about 41% of potential arable land of Ethiopia is acidic among which south Western part of the country is highly affected (Abebe, 2007).

Therefore, the efficient use of mineral fertilizers on infertile soil is recognized to be a quick and direct way of boosting crop production (Tarekegne and Tanner, 2001). The use of leguminous crops for this inert nitrogen fixation and incorporation into agricultural soil is getting prime importance in Ethiopian context (Woldemeskel, 2007; Bekere and Hailemariam, 2012; Bekere*et al*., 2013). In western Ethiopia, soybean reached a peak yield of 2406.7kg/ha with application of 46 kg P_2O_5/ha (Desta, 1986).Accordingly, nitrogen and phosphorus are, however, considered necessary for grain yield of soybean (Galarao, 1992).Soybean has a relatively high nitrogen requirement especially at later growing stages (Wantanabe*et al.*, 1983) and it has relatively higher phosphorus requirement which helps to stimulate root development (Patel *et al.*, 1992).

The low productivity of the crop is due to several constraints, including unbalanced plant nutrient (Sharma *et al.*, 1996) and plant population. The farmers have been attributed to lack of application of the right type and amount of fertilizers; poor soil fertility management, and poor agronomic management practices, such as improper weed management, inappropriate plant population and planting time. In addition, lack of improved varieties having desirable traits, such as nutrient use efficiency, disease resistance, and high yielding ability also magnified the problem. Therefore, this study was initiated with the objective to evaluate the response of soybean to different plant population and NP fertilizers in Kersa woreda of Jimma zone, south western Ethiopia.

2. LITERATURE REVIEW

2.1. Origin of Soybean

Soybean (*Glycine max* (*L.)*Merrill*)*is a legume native to East Asia perhaps in North and Central China (Laswai*et al.*, 2005) and it is grown for its edible bean, oil and protein around the world. They are eaten in fresh green state and dry beans. Soybean is found in Family Fabacea and Species. The earliest documentation existing that mentions soybean as one of the five main plant foods of China comes from the year 2700 B.C(Hymowitz and Shurtleff., 2005). The spread of soybean from its native land of origin has been mainly due to its adaptability and predominant use as a food crop for human nutrition, source of protein for animals, medicinal plant and lately as an industrial crop (Yusuf and Idowu, 2001).

2.2. Botany of Soybean

Soybean is a short-day plant, which is a very important oil and protein crop. It is an annual plant with height of about 1m to 1.5m. The plant has a main root that goes down in the depth of 1.5 meters to the ground. Its stem is straight and has multiple branches covered by brown color corks. This is a plant with three leaflets. The straight pods consist of 2-4 grains which is covered by thin pads. The grain color is yellow, green and black. It can grow on all types of soil, but deep fertile loam with good drainage is most suitable for growth (Whigham, 1974). There is also a potential to intercrop soybean with long stem crops such as maize and sugarcane (Jagwe and Owuor, 2004).

2.3. Agro Ecologies of Soybean

Soybean in Ethiopia could be grown from sea level up to 2200meter above sea level and with annual rainfall as low as 500-700 mm, but performs best between 1300 and 1800masl with annual rainfall of 900-1300 mm, an average annual temperature between 20-25°C and a soil pH of 5.5 to 7 (Gurmu, 2007). The growing season ranges from 90 to over 150 days and three different soybean varieties can be distinguished (Gurmu, 2010). Early maturing group with 90-120 days (Awassa-95, Williams, Crawford and Jallale), medium maturing group with 121-150 days (Clarck-63K, Cocker-240, Davis, Cheri and AFGAT), late maturing group with >150 days (Belessa-95 and Ethiougozlavia)

Soybean grows in areas where maize and common beans are grown. It grows to a height of 60–120 cm, maturing in 3 to 6 months depending on variety, climate and location. It is drought tolerant. At very high altitudes, flowering may not occur and the crop remains vegetative. Soybean is therefore a crop that requires warm climates and is suitable for low to medium altitudes (Ogema*et al*., 1988). It grows best when planted in pure stands. The presence of Rhizobium japonicum in the roots of soybean enables the crop to fix nitrogen in the soil contributing to improved soil fertility (Kasasa*et al*., 2000).

2.4. Soybean Production in Ethiopia

Soybean production in Ethiopia is steadily growing to meet the ever-increasing food and market demands. Moreover, some soybean varieties that are categorized into three maturity groups: early-, medium- and late-maturing varieties, are recommended for different agro-ecological zones of Ethiopia (Worku and Astatkie, 2011). It is a multipurpose crop, which can be used for a variety of purposes, including preparation of different kinds of soybean foods, animal feed, soy milk and raw material for the processing industry, and it has counter effectson depletion of plant nutrients in the soil, resulting from continuous mono-cropping of cereals, especially maize and sorghum, thereby contributing to increasing soil fertility (Hailegiorgis, 2010). Yield of legumes in farmers' field is usually less than 0.65t/ha against the potential yield of 1.2t/ha suggesting a large yield gap (CACC, 2002).

In Ethiopia, pulse crops rank second as food after cereals and occupy about 15.2% of the total cultivated areas and contribute about 11.9% of the total production (CSA, 2013). Haricot bean and soybean are the two main lowland food legume crops. According to Hailu and Kelemu, (2014), a ten year (2002 to 2012) soybean data showed that the land coverage and total production increased by 10 and 21 fold, respectively; with average productivity of 1.06 ton/ha. However, the amount of land allotted for the production of soybean is very low compared to land allocated for other oil crops (Hailu and Kelemu, 2014). It is one of pre-eminent crops in providing cheap protein (40%) and oil (20%) which determines the economic worth of the crop on the globe (Thomas and Erostus, 2008).

The importance of soybean emanates from the high nutritional value of its grain: 40% protein and 20% oil (Gurumu*et al*., 2009), making it an important raw material for food and oil processing industries; in crop rotation, due to its nitrogen fixing capacity that is important in improving soil fertility, and health benefits of its consumption (Tesfaye *et al*., 2010). According to (Birt*et al*., 2004), soybean consumption can prevent some chronic human diseases. It is also considered as a strategic crop in fighting the worlds' food shortage and malnutrition problems, and most food aids to displaced and malnourished people are fortified with soybean (Thoenes, 2014).

In Southwestern Ethiopia, where maize is the major staple food crop, and grown in mono crop condition, the importance of soybean for crop rotation is paramount. This is mainly because of the fact that mono crop system causes depleted soil fertility, and unbalanced diet to the maize feeders over time (Tesfaye, 2012). Including soybean in the crop rotation is an indigenous practice in Ethiopia that has agricultural and social benefits. Soybeans offer the benefit of nitrogen sparing, meaning that they use less of the available nitrogen in the soil compared to a non-fixing plants, thereby "sparing" it for the succeeding crop. They may also supply a residual effect, where the biomass of the legume plant is returned to the soil, nitrogen available in the plant will be degraded and released in an inorganic, plant-available form to the crop that follows the legume in rotation (Giller, 2001). Thus, they have been used for centuries to maintain an adequate nitrogen balance in the cropping system.

Soybean was introduced to Ethiopia in the 1960's (IAR, 1982). Despite this early introduction, it was not easy to achieve wider dissemination and production of soybean; especially among the small holder farmers. The main limitations for this were: lack of knowhow by the local farmers on how to utilize the crop, unavailability of an attractive market for the produce, and lack of a systematic approach for popularizing the crop through training female farmers on how to prepare different meals from soybean. Consequently, the proportion of land in the country on which soybean was grown remained low for several years (Tesfaye *et al*., 2010).

Besides, most farmers spare fertile soils for the production of cereals, especially maize, while pulses including soybean are grown on marginal soils usually for crop rotation. In addition, farmers sometimes apply below the optimum level, but usually do not apply commercial fertilizers on pulse crops in general, and soybean in particular. The main reasons for low use of commercial fertilizers by subsistence farmers have been poor financial capacity (Vance *et al.*, 2003), high price of commercial fertilizers, poorly developed rural transportation and distribution systems particularly during rainy seasons (Mesfin, 1980).

Consequently, subsistence farmers grow most crops including soybean under very low levels of soil nutrients. For a leguminous crop, such as soybean, Nitrogen (N) nutrition is not a serious problem; as the plant has the inherent ability to obtain most of its N requirement from the atmosphere through N fixation by forming a symbiotic relationship with Rhizobium bacteria in the soil. Soybean requires 378 kg/ha of nitrogen to complete its growth cycle; however, it has the potential to obtain 60 to 70% of its requirement from nitrogen fixation (Abendroth and Elmore, 2000). Nonetheless, this relationship could not occur without inoculating the seed with appropriate strain of Rhizobium bacteria, the optimum amount of "inocula", and proper method of inoculation. As the nitrogen requirement of the crop could be improved by nitrogen fixation; however phosphorus (P) nutrition remains the critical limiting factor of productivity. The problem is serious in developing countries where, according to Mesfin, (1980) commercial fertilizer use is very low or non-existent. Moreover, the proportion of available P is very low compared to the large P reserve in many soils. Al Abbas and Barber, (1964) indicated that total P is often 100 times higher.

The main production constraints responsible for low productivity of soybean in Ethiopia (i.e., national average yield 1410.1 kg/ha in the year 2010, which is far below the potential productivity of the crop in the research fields i.e., 2000-3500 kg/ha) (Tesfaye, 2007) are: poor soil fertility management practices, soil borne diseases, bird damage at early seedling stage, and low nutrient availability associated with pH of the soil. More importantly, the major soybean producing areas in South Western Ethiopia are characterized by high rainfall and acidic soil, which is also associated with high P fixation, and low P availability. In addition, farmers have limited capacity to purchase and apply commercial fertilizers, which is the principal cause of a very low productivity of soybean in Ethiopia. Hence, identifying crop varieties, which performs well under P deficient soils and respond to high level of P, is gaining priority in several breeding programs (Tesfaye, 2007).

2.5. Growth and yield response of Soybean to N and P fertilizers and plant population

Phosphorus (P) and nitrogen (N) play specific role in symbiotic N_2-fixation through their effects on nodulation and N_2-fixation process (O' Hara *et al.*, 2002). Symbiotic nitrogen fixation has a high P demand because the process consumes large amounts of energy (Schulze *et al*., 2006) and energy generating metabolism strongly depends upon the availability of P (Israel, 1987). Nodules are strong P sinks and nodule P concentration normally exceeds that of roots and shoots (Drevon and Hartwig, 1997). Soybean can be grown on almost all well-drained soils; however, the crop is more productive on fertile loam soils. For efficient production as a mono-crop, soil must be managed properly to allow optimum uptake of water and nutrients (Varco, 1999). Fertilizer application is important in the soybean production and has great effect on yield. A report indicated that application of 18 kg N /ha and 46 kg $P_2O_{5/}$ ha will give better yield (Anonoymous, 2002).

Nitrogen requirement for soybean are typically met by a combination of soil-derived and nitrogen provided through the process of symbiotic fixation from Rhizobia bacteria in root nodules. In general, there was an increase in plant height and dry matter accumulation per plant in soybean (Manral and Saxena, 2003). Varon*et al. (*1984) have reported an increase in plant height with the application of nitrogen fertilizer. Improved plant nutrition, particularly nitrogen (N) uptake, has contributed to increased soybean yield. Adequate N supply throughout the growing season is important for high yield (Salvagiotti*et al.*, 2009). Nitrogen uptake is highest during early seed filling (Gutierrez-Boem*et al.*, 2004). Uptake during the seed filling period may be reduced due to the decline of nitrogen fixing bacteria and insufficient soil N (Salvagiotti*et al.*, 2009). To compensate, soybean remobilizes N from leaves causing senescence (Gutierrez-Boem*et al.*, 2004).

Phosphorus (P) is a major growth-limiting nutrient, and unlike the case for nitrogen, there is no large atmospheric source that can be made biologically available (Ezawa*et al.*, 2002). Soybean responds to P-fertilization and soil P level as well as soil location (Ogoke*et al.*, 2003). In the dry savanna zone of Nsukka (Southeastern Nigeria), significant response of soybean to 20 kg N and

20 kg P_2O_5/ha has been observed (Ochulor, 1999), however, obtained no response due to the high level of phosphorus in the experimental site. The importance of phosphorus in biological nitrogen fixation is well known, as it is an energy driven process (Haru and Ethiopia, 2012). Soil P dynamics is characterized by physicochemical (sorption-desorption) and biological (immobilization-mineralization) processes. P is needed in relatively large amounts by legumes for growth and nitrogen fixation and has been reported to promote leaf area, biomass, yield, nodule number, nodule mass, etc., in a number of legumes (Kasturikrishna and Ahlawat, 1999).

Phosphorus deficiency can limit nodulation by legumes and P fertilizer application can overcome the deficiency (Carsky*et al.*, 2001). Large amount of P applied as fertilizer enters in to the immobile pools through fixation reaction with highly reactivecation Aluminum (Al^+) and Iron ($Fe3^+$) in acidic, and Calcium (Ca^{2+}) in calcareous or normal soils (Gyaneshwar*et al.*, 2002). Efficiency of P fertilizer throughout the world is around 10 - 25% (Isherword, 1998), and concentration of bioavailable P in soil is very low reaching the level of 1.0 mg kg soil (Goldstein, 1994). Soil microorganisms play a key role in soil P dynamics and subsequent availability of phosphate to plants (Richardson, 2001). Microbial community inf1uences soil fertility through soil processes viz. decomposition, mineralization, and storage/release of nutrients. Phosphorus specifically, enhances photosynthesis rates, enzymatic activity, root development, uptake and transfer of other nutrients and seed germination (Hao*et al.*, 2002). Phosphorus deficiency is reported to reduce nodule formation and growth while an adequate supply leads to good development of nodules (Wall *et al.*, 2000).

2.5.1. Effects of Planting Density

Plant population is an important agronomic factor that manipulates micro environment of the field and affects growth, development and yield formation of crops. Within certain limits, increase of plant population density decreases the growth and yield per plant but the reverse occurs for yield per unit area (Caliskan*et al*., 2007). Higher populations can contribute to improved soybean yields as well. Monsanto demonstration trials have shown higher populations improve yields, but can vary by relative maturity. It was found in 2011 that soybean yield increased with an increase in population from 140,000-200,000 seeds/acre and for a 3.1relative maturity soybean products but the yield remained the same or decreased with an increase in population for the 2.9 and 3.3relative maturity products (Caliskan*et al*., 2007). Final plant population depends on seedbed conditions and planter settings. Poor seedbed conditions, seed quality, inaccurate planter adjustment, soil crusting, extremely wet soil, disease and insect pressure, and hail or frost damage are factors that can reduce plant population. Increased plant population potentially could be used in a narrow row system to maximize space utilization. Prior research results indicate that optimal plant population can be obtained in a narrow row spacing system (Devlin *et al.*, 1995;Oplinger and Philbrook, 1992). Greater seeding rate is usually required to achieve the intended final plant population. Iowa State University estimates a 15 to 30% increase in seeding rate over the desired final plant stand and this is recommended to compensate for any plant loss (Pedersen, 2008).

Adjusting planting density is an important tool to optimize crop growth and the time required for canopy closure, and to achieve maximum biomass and grain yield (Liu *et al.*, 2008). High populations provide a way to optimize grain yields in short-season production systems (Liu *et al.*, 2006b).

2.5.2. Number of Leaves Per Plant

Application of fertilizers at the rate of 20 kg N with 35Kg P_2O_5/ha gave greater number of leaves and branches in soybean (Orellana*et al.*, 1990). Nitrogen supply has large effect on leaf growth because it increases the leaf area of plants and, in that way, it influences on photosynthesis function (Bojovi ć *et al*., 2009). In legumes and other leafy vegetables, N improves the quality and quantity of dry matter and protein (Uchida, 2000). Green colour in the leaf is vanished due to nitrogen deficiency and this may cause the decrease in leaf area and intensity of photosynthesis as well (Chu *et al*., 2005). P is limiting, the most prominent effects are a reduction in leaf expansion, leaf surface area and the number of leaves (Bekere*et al*., 2012).Nitrogen and Phosphorus are the major component of the leaf chlorophyll, which influences the plant to manufacture its own food through photosynthesis process, which ultimately increases yields and uptake of important nutrients in different plant tissues (Imsande, 1989).

2.5.3. Plant height

Plant height is one important agronomic trait in soybean cultivar selection. This selection is based on the association of these agronomic traits with seed yield and stability (Hiebsch*et al.*, 1990) indicates that soybean plant height increased with higher seeding rate and narrower row width. It can also be affected by planting date and the effect varies according to different growth habits or locations (Pedersen and Lauer, 2003). According to Weaver *et al.*, (1991) indicated plant height of indeterminate was reduced more with late planting. Plant height can be affected by planting date, but the result is location dependent (Pedersen and Lauer, 2003).

2.5.4. Number of branch per plant

According to Boquet, (1990) found that increasing plant population density can decrease both branch and main stem yields per plant. It resulted in a decrease in total branch yield but an increase in total stem yield because the increase in plant population offsets the stem yield loss but not the branch yield loss. An increase in plant population was necessary to obtain higher yields at later planting dates for determinate soybean planted in narrow rows. Soybean has the ability to compensate for low plant population densities through increased branching pods per plant, and seeds per plant (Ball *et al.*, 2000).

2.5.5. Leaf area

Leaf area compensation for defoliation may be expressed through changes in new leaf area expansion or in normal plant senescence. Experimental data measuring leaf area recovery were reported by Gazzoni, (1974), who found a general trend of high recovery when applied on vegetative stages, with recovery indexes being more intense at high defoliation levels. Ostlie and Pedigo, (1985) noted that soybeans compensated for development retarded by drought through the rapid addition of new leaves and increased leaf area expansion when normal rain resumed. Soybean accumulation of photosynthetic energy, and the way this energy is divided between structural and reproductive components. Through their data, the same authors concluded that yield reductions were proportional to reduction in total plant weight; therefore soybean compensation evaluated by increased partitioning of energy was not present. The decrease in nitrogen content in the leaves and stems after bloom indicated translocation to pods and seeds, in spite of total nitrogen accumulation persisting late in the growth cycle.

2.5.6. Number of Nodules

According to Nyoki and Ndakidemi (2014), inoculation is not usually favoured below pH 5.5, and application of various levels of P did not produce nodule numbers that were significantly higher than the control plots. This finding is similar to the reports of Bekere and Hailemariam(2012),which showed that no differences in nodule number were produced when different phosphorus levels were used in Ethiopia.Tahir *et al*, (2009) have been reported increase in nodule numbers with the use of inoculant.P stress reduces nitrogen fixation due to decreased nodule formation and reduced nodule sizes and finally affecting the yield, both grain quality and quantity (Sadeghipour and Abbasi, 2012).

2.5.7. Number of Pod per plant

Plant density affected soybean yield and yield components in narrow rows (Epler and Staggenborg, 2008). As plant population was increased, pods per plant decreased steadily; however, yield was not reduced by the loss of pods per plant, because pods per area increased as plant population increased (Robinson and Wilcox, 1998). Usually soybean Seed yield increases with decreasing row width up to a certain point (Oplinger and Philbrook, 1992), after that a further decrease in row width may negatively affect seed yields (Board and Harville, 1992). Increasing levels of nitrogen fertilization increased the number of pods per plant as indicated by (Tola, 1995). Similar results were reported by other investigators (Agha *et al.,* 2004; Akbari, 2001; Xuewen, 1990). In contrast, Maneechote, (1991) and Hantolo, (1995) observed that increasing the levels of nitrogen fertilization had no effect on mean number of pods per plant. Although, Hassan, (1987) reported that rhizobium inoculation had no effect on mean number of pods per plant in soybean, the work done by Dadson and Acquaah, (1984) showed that rhizobium inoculation decreased the mean number of pods per plant.

2.5.8. Number of Seed per pod

In most legume plants, the number of seeds per pod for any given cultivar is a relatively stable character (Chapman, 1981). In soybean, the number of seeds per pod was slightly affected by the levels of nitrogen fertilization as noticed by others (Agha *et al.,* 2004; Akbari*et al.,* 2001). On the other hand, Hassan, (1987) stated that in soybean rhizobium inoculation had no effect on mean number of seeds per pod.

2.5.9. Harvest index

Harvest index of soybean increased withincreasing plant population (Edwards and Purcell, 2005). It was relatively stable and was not affected by population (Ball *et al.,* 2000). Roy *et al*., (1995) found that soybean seeds inoculation increased the nodules number per plant and thus increasing harvest index. Harvest Index is a measure of crop yield in that it expresses the weight of the harvested product as a percentage of the whole plant weight of the crop.

2.5.10. Grain yield

The work done by Starling *et al.* (2000) showed that plant growth and grain yield of soybean were higher when fertilizer nitrogen was applied as starter. Grain yield response of soybean to the nitrogen application may be because nitrogen plays an important role in the synthesis of chlorophyll and amino-acids which are the indispensable ingredients of the process of autotrophization. Nitrogen influenced grain yield through source–sink relationships resulting in higher production of photosynthesis and their increased translocation to reproductive parts Tripathi*et al.* (1992).

3. MATERIALS AND METHODS

3.1. Description of the Study Area

Jimma Zone is divided in to 13 woreda as (hosting a total population of over 2.2 million) with an agro-ecological setting of highlands (15%), midlands (67%) and lowlands (18%). The zone is one of the major coffee growing areas of Oromia region well-endowed with natural resources contributing significantly to the national economy of the country. The major crops grown, other than coffee, are maize, teff, sorghum, barley, pulses (soybeans, beans and peas), root crops (enset-false banana and potato) and fruits. Teff and honey production are another sources of cash after coffee. Enset is a strategic crop substantially contributing to the food security of the zone and is especially important in Setema and Sigimo woreda (highlands). In normal years, the rainy season extends from February to October. Bordered on the south by Dedo, on the southwest by SekaChekorsa, on the west by Mana, on the north by LimmuKosa, on the northeast by TiroAfeta, and on the southeast by Omo Nada.

The study was conducted in Kersa woreda of Jimma Zone, South western Ethiopia, under rain fed condition during the main cropping season in 2015/2016. The site is located at about 318 km from Addis ababa and 28 km East of Jimma town (7° 4′00″ N latitude and 36° 50′ 0″ E longitude) at an altitude of 1740 masl. The average annual maximum and minimum air temperatures are 28.8 ^{0}C and 11.8 ^{0}C, respectively and the area receives adequate amount of rain fall, ranging from 1,200 to 2,800 mm per annum cropping season. According to Van Ranst*etal. (*2011), the major reference soil groups in the Gilgel-Gibe catchment are Nitosols, Acrisols, Ferralsols, Vertisols and Plano sols. The middle and high altitude soils are less rich in nutrients due to the fact that they have been under human land use practices for long period of time (BPEDORS, 2000). The soil type of the experimental area was Nitsol (Reddish brown) with a pH of around 5.2.

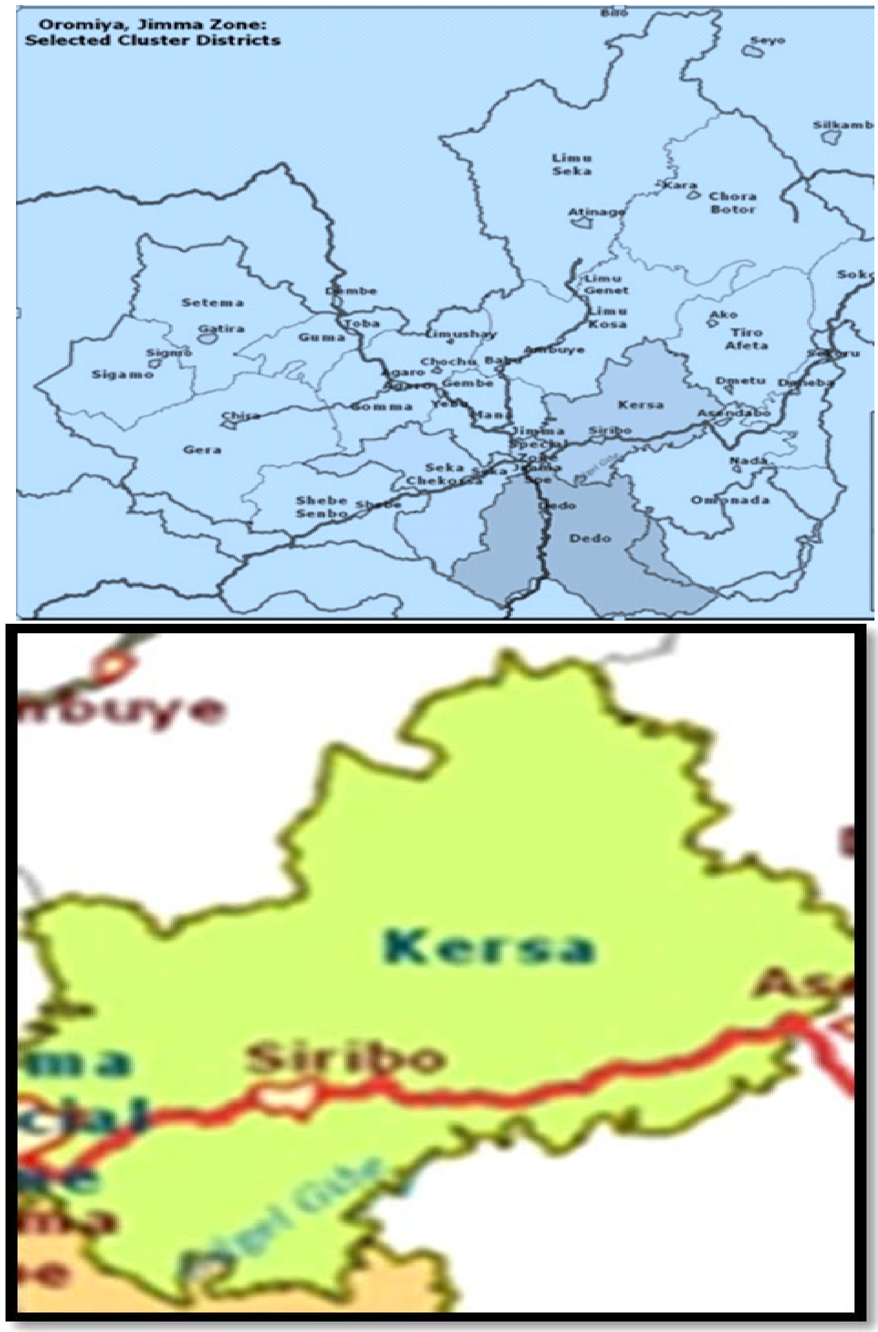

Figure.1 Map of the study Area

3.2 Planting material

The soybean variety named (Clark-63K), which was developed and released byHawassaAgricultural Research Centre in 1982 was used for the experiment. Clark-63K is a highyielding cultivar adapted to a wide range of altitudes 300-1800masl and annual rain fall of 450-1500mm. The yield capacity of the crop both in research and farmers field was 15-25and 9-11qt/ha respectively. Whereas its maturity date was medium 121-150 days ((EARO, 2004)and ffertilizersUrea and DAP) were used as a source of nitrogen and phosphorus nutrient elements.

3.3. Treatment and Experimental Design

Table: 1 Treatment combinations

Treatments	NP fertilizer(kg ha^{-1})	Plant population(pl/ha)	Treatment Combinations
1	23/23	166,667	N1P1Pop1
2	23/23	166,667	N1P1Pop2
3	23/23	166,667	N1P1Pop3
4	23/23	166,667	N1P1Pop4
5	23/46	200000	N2P2 Pop1
6	23/46	200000	N2P2 Pop2
7	23/46	200000	N2P2 Pop3
8	23/46	200000	N2P2 Pop4
9	46/46	333333	N3P3 Pop1
10	46/46	333333	N3P3 Pop2
11	46/46	333333	N3P3 Pop3
12	46/46	333333	N3P3 Pop4
13	69/69	400000	N4P4 Pop1
14	69/69	400000	N4P4 Pop2
15	69/69	400000	N4P4 Pop3
16	69/69	400000	N4P4 Pop4

NP fertilizer = 23/23 kg/ha, 23/46 46/46, and 69/69 Kg/ha, and coded as N1P1, N2P2, N3P3 and N4P4, respectively and plant population levels = 166,667, 200,000, 333,333 and 400,000 (Plant /ha) also coded as Pop1, Pop2, Pop3 and Pop4, respectively.The experiment was carried out with factorial arrangement in RCBD with three replications. Thus, there were a total of 16 treatment combinations.

The experimental field consisted of forty-eight plots. Gross plot size was 5m x 4m ($20m^2$) each accommodating 6 rows and the spacing between plots and blocks were 0.8m and 1 m, respectively, leaving the outer most rows on both sides of each plot to avoid border effects.

The four plant populations were 166,667, 200,000, 333,333 and 400,000 plants/ha, while the size of plot was equal for all and only the difference was between plant and row spacing. The trial was compared with previously done activities both on fertilizer and plant populations includes, 23/46kg/ha of NP and 333,333, respectively.

3.4. Experimental Procedures

The land was prepared on a farmer's field by removing all unwanted materials. Before sowing the crop, the field was plowed with oxen three to four times to make a fine seed bed, but depend on type of soil. The source of N and P was urea and DAP, respectively. As blanket recommendation, 100 kg DAP and 50 kg urea per ha were used for soybean [*Glycine max (L)* Merrill] around Ilubabor and Jimma (Getachew *et al*., 1987). The soybean seeds were drilled in rows during the growing season on June 14, 2015 and thinned after emergence. The land was previously cropped with sorghum. The other management practices were applied as per the recommendation for the crop. The rate of nitrogen applied at time of planting was 9, 18, 18 and 27 kg/ha, while after thinning 30, 11,61 and 91kg/ha

3.5. Soil Sampling and Analysis

Acomposite soil sample was collected in a diagonal pattern from 0-20cm soil depth before planting and after harvesting. Uniform slices and volumes of soils were obtained in each sample by vertical insertion of an auger. The samples were air-dried, ground using a pestle and a mortar and allowed to pass through a 2 mm sieve. Working samples were prepared and analyzed at JARC soil laboratory for the selected physico-chemical properties. These include, texture, particle size distribution, soil pH, organic carbon, total N, available phosphorus and cat ion exchange capacity (CEC) using standard laboratory procedures. Soil pH was determined from the filtered suspension of 1:2.5 soils to water ratio using a glass electrode attached to a digital pH meter (potentiometer) (Page, 1982). Texture of the soil was determined by the hydrometer method. The soil was analyzed for total nitrogen, available phosphorus, CEC, and organic carbon contents. Organic carbon and total nitrogen were determined by the method of Walkely and Black and Kjeldhal methods, respectively (Jackson, 1973). Available phosphorus was determined using Bray II extraction method as described byVan Reeuwijk, (1992). Phosphorus in the extracts was determined with atomic absorption spectrophotometry calorimetrically according to the molybdenum blue color method described by Murphy and Riley (1962).

3.6. Data Collected

3.6.1. Growth parameters

Days to 50% flowering

It was determined by counting when 50% of the plants in the plot start to flower.

Days to 50% maturity

It was recorded when 50% of the plants showed a change in leaf color from the lower part toupper partthe plant. This was when plants showed a color change by half and expected to be harvested after 45 days.

Number of nodules per plant:

It was determined as the total number of nodules per plant when 50% days of the plants in a plot start flowering and it was counted using five randomly selected plants per plot. It was total number of nodules per selected plants in each plot(Tahir *etal*., 2009).

Number of leaves per plant

It was determined as the total number of leaves per plant at flowering and at physiological maturity stages using five randomly selected plants per plot.

Number of branches per plant

It was estimated by counting the number branches of five randomly selected plants from each plot at maturity stage (Tesfaye *etal*., 2011).

Total Leaf area per plant

It was measured for five plants, which were randomly taken from the two border rows, using leaf area meter (LI-3100C leaf area meter) and the average values was calculated for a plant(Tahir *etal*., 2009).

Plant height

It was measured using ruler from the ground level to the tip of the plant at flowering and at physiological maturity and five randomly selected plants were taken from each plot for this purpose.

Total Fresh weight leaves per plant

It was measured from using five plants taken from the two border rows of each plot by using sensitive balance before oven drying and the average was estimated.

Total Dry weight of leaves per plant (g)

It was measured using five randomly taken mature plant from each plot after oven drying at 70^{o}C until constant weight is attained the average value was calculated. After the weight was measured using digital balance, and percent dry matter was calculated using the formula:-

DW (%) = ([(DW+CW)-CW])/ ([(FW+CW)-CW]) X100

Where:

DW=dry weight

CW=container weight

FW= fresh weight (Tahir *etal*., 2009).

3.6.2. Yield and yield components

Number of pods per plant

The number of pods was counted for five randomly selected plants from the four middle rows of each at the time of harvesting and their averages were recorded(Kamara *etal*., 2007).

Number of seeds per pod

It was determined as the total number of seeds per pod in each plot at the time of harvesting using the five randomly selected plants from each plot (Tesfaye *etal*., 2011).

Pod length (cm)

It was measured at harvesting using pods of five randomly selected plants and the average was recorded.

Hundred seed weight

The weight of 100 seeds was taken from each plot at the time of harvesting, after adjusting the moisture content of the seeds between 10% and 13 %(Kamara *etal*., 2007).

Total Dry Biomass yield (kg/ha)

Plants from the net plot area were harvested at physiological maturity, and weighed after plants dry including all above ground (Kamara *etal*., 2007).

Grain yield (kg/ha)

It was measured for each plot and converted into hectare basis (Tesfaye *etal*., 2011).

Harvest index

It was expressed as the ratio of economic yield per plant to the total above ground biomass.

$$HI = \frac{GY\ (kg/ha)}{TBY\ (Kg/ha)}$$

Where,

HI= harvest index

GY=Grain yield (at 10% moisture base)

TBY=Total dry biomass yield (Tesfaye *etal*., 2011)

3.7. Stastical Analysis

The collected data were summarized, checked through normality test by Minitab and statistically analyzed with the Analysis of Variance (ANOVA) procedure out lined for factorial experiment in a RCBD using SAS software (SAS, 2002). Treatments means that differed significantly were separated by using the LSD procedure at 5% probability level. Correlation coefficient was determined for parameters using the same software.

3.8. Partial Budget Analysis (Economic Analysis)

An economic assessment was done using partial budget procedure described by CIMMYT, (1988). The variable costs including the cost of DAP and urea were taken at time of planting from socio-economic research group of Jimma Agricultural Research Center (JARC) and the price of soybean grain data were taken from office of Kersa Woreda Trade, Transportation and marketing. Labor cost per treatment was recorded and used for this analysis. The average yield was adjusted downward by 10% to reflect the farmer's field yield asdescribed by CIMMYT, (1988).

All costs and benefits were calculated on Ethiopian Birr (EtB)in hectare basis. The inputs used in the partial budget analysis were mean grain yield of each treatment, field price of soybean grain (sale price minus the costs of harvesting, threshing, winnowing, bagging and transportation), gross field benefit (GFB) /ha (the product of field prices and mean yield for each treatment), field price of N and P /kg (nutrient cost plus the cost of transportation from the point of sale to the farm), the field cost of N and P (the product of the quantity required by each treatment and the field price of fertilizer), the total costs that varied (TCV), which included the sum of field cost of fertilizer, its application and seed cost.

The net benefit (NB) was calculated as the difference between GFB and TCV. Marginal rate of return (MRR) was calculated as the ratio of differences between net benefits of successive treatments to the difference between total variable costs of successive treatments or the net return was calculated as total gross return minus total variable cost.

4. RESULTS AND DISCUSSION

4.1. Phenological Growth Parameters

4.1.1. Days to 50% Flowering

The effect of plant population and NP fertilizer on days to 50% flowering was given in Table 2 and Appendix Table 3. NP fertilizer showed significant at $P<0.05$, while the interaction and plant population did not show significant variations for days to 50% flowering. The maximum days to 50% flowering were recorded for Pop3 (61.51), while the minimum value was recorded for Pop2 (58.87). The maximum days to 50% flowering were recorded for N4P4 (71.99), while theminimum days were recorded for N1P1 (50.85). Higher plant population and NP fertilizer rate prolong the flowering stage of soybean probably due to the low availability of nutrient. It could be also due to the fact that application of excessive nitrogen prolonged vegetative growth and flowering of soybean. This result agrees with some finding previous (Brady and Weil, 2002) which shows that phosphorous is helpful in flowering and hastens maturity of crops if applied in single dose without nitrogen. The results showed that nitrogen had delayed flowering, pod setting and maturity dates of soybean in this experiment because nitrogen enhances vegetative growth.

4.1.2. Days to 50% maturity

The effect of plant population and NP fertilizer showed significant difference at $P<0.01$, while the interaction did not show significant effect on days to 50% physiological maturity (Table 2 and Appendix Table 3). The maximum value of days to 50% maturity was recorded for Pop2 (124.15), while minimum value for Pop4 (107.54). The maximum value of days to 50% maturity for NP fertilizer was recorded for N4P4 (127.22), while the minimum value was recorded for N1P1 (106.41). This could be due to the fact that the maximum plant population favors earlier maturity due to competition fornutrients, light and moisture, while in lower plant populations may be prolonged vegetative growth. Similarly, at high NP fertilizer rates plant matured later, probably because of higher soil nutrient various vegetative growth rather than maturity, while at low NPfertilizer rates plants matured earlier probably due to shortage of the resources. The current study agreed with that of (Wood *et al.*, 1993)who reported that application of N fertilizer significantly delayed physiological maturity of soybean.

Table: 2 Effect of plant population and NPfertilizer rate on days to 50% flowering (DF) and days to 50% maturity (DM) of Soybean in Kersa Woreda of Jimma zone, south western Ethiopia

Plant population	DF	DM
Pop1	59.55[a]	119.32[ab]
Pop2	58.87[a]	124.15[a]
Pop3	61.51[a]	115.04[b]
Pop4	59.82[a]	107.54[c]
LSD(0.05)	ns	5.7567
NP fertilizer		
N1P1	50.85[a]	106.41[a]

N2P2	55.37[b]	110.27[a]
N3P3	61.55[c]	122.15[b]
N4P4	71.99[d]	127.23[b]
LSD(0.05)	3.27	5.75
CV (%)	6.54	5.92

Means followed by the same letter(s) with in a column for a given treatment levels are not significantly different at 5% p level

4.2. Vegetative Growth and Root Nodule

4.2.1. Plant height

The analysis of variance for the effect of plant population and NP fertilizer on plant height is given in Table 2 and Appendix Table 3. The results revealed that the main effect of plant population and interaction were non-significant, while NP fertilizer were showed significant difference at P<0.05. The maximum plant height was recorded for Pop1 (48.23cm) and the minimum was recorded for Pop4 (44.39). The maximum plant height was recorded for N4P4 (52.55cm), but the minimum value was recorded for N1P1 (38.81). This indicates that as plant population increases plant height decreases and also, as NP fertilizer increase there is plant height increases, which creates lodging problems, low branching and low pod per plant. As the number of plants increased in a given area the competition among the plants for nutrients uptake and sunlight interception also increased and the plant population and NP fertilizer was available for the plant.

This experiment is not in agreement with the findings of Elmore (1991), who reported increased plant height was associated with plant population, but only as final stands were lodging was not a significant problem with greater seeding rates. Conversely, provided that lodging does not increase, taller plants can lead to less grain loss during harvest and greater grain yields (Markos*et al.*, 2012).

4. 2. 2. Number of leaves per plant

The effect of plant population and NP fertilizer showed significant difference for leaf number per plant at $P<0.01$ and $p<0.05$ respectively, while the interaction did not show any significant difference (Table 3 and Appendix Table 3). The maximum number of leaves was produced for Pop1 (75.39), while the minimum was recorded for Pop3 (69.20). The maximum leaf number for NP fertilizer was recorded for N4P4 (83.07), while the minimum leaf number was recorded for N1P1 (61.92). Number of Leaves reduced with higher plant population, and this might be due to competition for assimilates, sunlight, moisture and nutrients, as the applied NP fertilizer is more consumed at higher populations. This result is in agreement with the findingsAkbari*et al*., (2001), who reported that increased levels of nitrogen fertilization increased the mean number of leaves per plant. However, Xuewen, (1990), showed that different nitrogen levels had slight influence on mean number of leaves per plant.

4.2.3. Total Leaf area per plant

Statistical analysis of the data revealed that the interaction of plant population and NP fertilizer was non-significant, while the effects of NP fertilizer and plant population was significant($P<0.01$)(Table 3 and Appendix Table 3). The maximum leaf area for plant population was recorded at Pop1 (174.04cm), while the minimum value was recorded for POP4 (149.27cm). The maximum value of leaf area was recorded for N4P4 (180.47cm), while the minimum valuewas recorded for N1P1 (150.47cm).

This is probably because of the effect of the plant competition for resources in higher plant populations and lower NP fertilizer rates. Higher NP fertilizer rates and plant populations resulted in larger leaf area, which could be because of a reduction in competition for space, moisture, sunlight and nutrients and an adequate nutrient supply to maintain and support lower plant populations. This result was in agreement with the findings of Harder *et al.*(2007) indicating that increasing plant population increased leaf area until the later reproductive stages. It has also been reported that Yield increases can be attributed to a greater leaf area index (LAI) in narrow compared to wide rows, andNPK (15:15:15) treated plots gave higher leaf area, followed by poultry manure, probably because of their capacity to release nutrients to plants faster with higher N content and lower C:N ratio (Awodun, 2007).

4.2.4. Total Fresh weight of the leaves per plant

Data regarding the effect of plant population and NP fertilizer on total fresh weightleaves per plant was given in Table 3 and Appendix Table 3. Statistical analysis of the data revealed that NP fertilizer and the interaction were non-significant, while theplant population was significant at P<0.01. The maximum total fresh weight of leaves per plant for plant population was recorded at Pop1 (41.84g), while the minimum value was for Pop4 (27.87g). The maximum fresh weight of leaves for NP fertilizerwas recorded for N3P3 (36.10g), while the minimum value was recorded for N4P4 (33.20g). This probably because of the leaf fresh weight is directly related with photho-syenthensis and it's assimilating for the photosynthesis through photo synthetically active radiation and the growth facilitation of the plant with respect to vegetative growth. The current experiment aligned with the studies of Rahman*et al*, (2004) have reported that as the plant growth and yield components increased at lower densities, yield per unit area decreased as a result of less canopy unit area with lower rate of photosynthesis and dry matter accumulation. Thus, the insufficient development of the canopy of leaves at earlier reproductive phase at lower densities limits yield (Edwards *et al.*, 2005).

4.2.5. Total Dry weight of leaves per plant

The interaction and NP fertilizer was non-significant, while the plant population was showed significant difference P<0.05 for leaf dry weightTable 3 and Appendix Table 3. The maximum value was recorded for Pop1 (9.10 g), while the minimum value was recorded for Pop3(6.85 g). Although it was not significant the maximum leaf dry weight was recorded for N1P1 (7.87 g), while the minimum value was recorded for N2P2 (7.65 g). This is probably because the leaf dry weight is directly related with grain yield of the plant which compensates competition among the plant and applied NP fertilizer with the plant population.

The current study agreed with the findings ofTaylor and Philadelphia, (2006) who reported that phosphorus supply increased the top dry matter production at flowering and the dry matter production of seeds, pod shells, and roots at late pod filling of inoculated soybeans. However, Ebie and Ayolagha, (2006) also observed that poultry manure gave the highest dry matter.

Table: 3 Main effect of plant population and NP fertilizer on Plant height (PH), Leaf area(LA), number of leaves(NL/plant), Leaf fresh weight(FW) and Leaf dry weight(DW) of Soybean in kersa woreda of Jimma zone, south western Ethiopia

Plant population	PH(cm)	NL	LA(cm^2)	FW(g)	DW(g)
Pop1	48.23[a]	75.39[a]	174.04[a]	41.84[a]	9.10[a]
Pop2	46.24[a]	73.67[ab]	168.55[a]	39.86[a]	8.625[a]
Pop3	44.39[a]	69.20[b]	163.22[a]	28.53[b]	6.44[b]
Pop4	44.39[a]	70.35[b]	149.27[b]	27.88[b]	6.85[b]
LSD(0.05)	ns	4.48	11.48	6.30	1.41
NP fertilizer					
N1P1	38.82[b]	61.92[d]	150.47[c]	35.09[a]	7.87[a]
N2P2	46.41[ab]	68.20[c]	160.44[bc]	33.69[a]	7.66[a]
N3P3	45.62[ab]	75.42[b]	163.71[b]	36.11[a]	7.75[a]
N4P4	52.55[a]	83.07[a]	180.47[a]	33.21[a]	7.73[a]
LSD(0.05)	8.19	4.48	11.48	ns	ns
CV (%)	21.44	7.46	8.42	21.90	24.23

Means followed by the same letter(s) within a column for a given treatment level and variable are not significantly different at 5% p level

4.2.6. Number of branches per plant

Analysis of variance for the effect plant population and NP fertilizer on number of branches per plant was given in Table 4 and Appendix Table 3. It was observed that plant population,NP fertilizer and their interaction had highly significant effect $P<0.01$. The maximum number of braches was recorded for N2P2xPop4 (8.06), while the minimum value was observed for N1P1xPop1 (2.26). In general with increasing plant population and NP fertilizer rate number of braches per plant increases. It is because the minimum plant population has high branches per plant due to low completion and the applied nutrients are sufficient for branching. Besides, maximum branching indicates maximum yield, which can compensate for the low population. Yield through branching and number of pods per plant and number of seeds per pod. In field studies investigating population effects, increasing plant population m^{-2} resulted in decreased number of branches per plant, and decreased the number of pods per plant (Boquet, 1990).Branching typically occurs at low plant populations in order to maximize yield (Carpenter and Board, 1997).

Table: 4 Interaction effect of plant population and NP fertilizer on Number of branches per plant of Soybean inKersa Woreda of Jimma zone, south western Ethiopia

NP fertilizer	Plant Population			
	Pop1	Pop2	Pop3	Pop4
N1P1	2.26^{d}	3.10^{d}	2.73^{d}	2.36^{d}
N2P2	3.33^{d}	5.23^{c}	5.43^{c}	8.06^{a}
N3P3	5.30^{c}	6.06^{bc}	5.93^{bc}	5.70^{bc}
N4P4	6.26^{bc}	6.36^{bc}	7.06^{ab}	6.56^{abc}
LSD (0.05)	1.52			
CV (%)	17.99			

Means followed by the same letter (l) with in columns and rows are not significantly different at 0.05 probability level.

4.3.7. Number of nodules

The interaction andNP fertilizer showed significant at P<0.05 and P<0.01 respectively for number nodules per plant Table 5 and Appendix Table 3, while plant population did not showed significant different. The maximum number nodules was recorded at N3P3xPop4 (8.66) ,while the minimum number was observed for N1P1xPop1 (3.36). This is because of the soil of experimental area was affect by environmental factors like acidic soils and couldn't fix any environmental nitrogen through rhizobium bacteria which facilitates low number of nodules at minimum fertilizer which contradicting one another. This resultshows that application of NP fertilizer without inoculation of a seed with rhizobium bacteria can improve root development and nodulation for the plant. This result agrees with Giller (2001) who reported that the application of phosphorous is improves root development, providing more infection sites for rhizobia, hence, encouraging nodulation.

Table: 5 Interaction effect of plant population and NP fertilizer on number of nodules per plant of Soybean at Kersa Woreda of Jimma zone, south western Ethiopia

NP fertilizer	Plant population			
	Pop1	Pop2	Pop3	Pop4
N1P1	3.36^{h}	5.30^{defgh}	3.76^{fgh}	4.50^{fgh}

N2P2	5.56[cdefg]	5.13[efgh]	5.50[cdefg]	5.06[efgh]
N3P3	6.36[bcdef]	7.40[abcd]	5.26[efgh]	8.66[a]
N4P4	6.80[abcde]	7.43[abc]	7.96[ab]	6.56[abcdef]
LSD (0.05)	2.12			
CV (%)	17.66			

Means followed by the same letter (l) with in columns and rows are not significantly different at 0.05 probability level.

4.3. Yield and yield components

4.3.1. Number of pods per plant

Statistical analysis revealed that of plant population; NP fertilizer and their interaction were significantP<0.01 for number of pods per plantFigure 2 and Appendix Table 3. The maximum number of pods per plant was recorded at combination of N2P2x Pop4 (67.26), While, the minimum number was resulted from N1P1xPop4 (25.66). The increase in number of pods per plant with increasing NP fertilizer rate might be due to availability of more resources to plants regardless of population density. This result also agrees with the findings ofLueschen and Hicks, (1977), indicating that soybean plants are capable of compensating for low densities by producing more branches and pods, resulting in yield levels remaining relatively constant over a wide range of populations. Increasing levels of nitrogen fertilization increased the number of pods per plant. As indicated by Tola (1995). Pod number per plant decreased while plant number in a unit area increased or plant population increased, pods per plant decreased steadily.

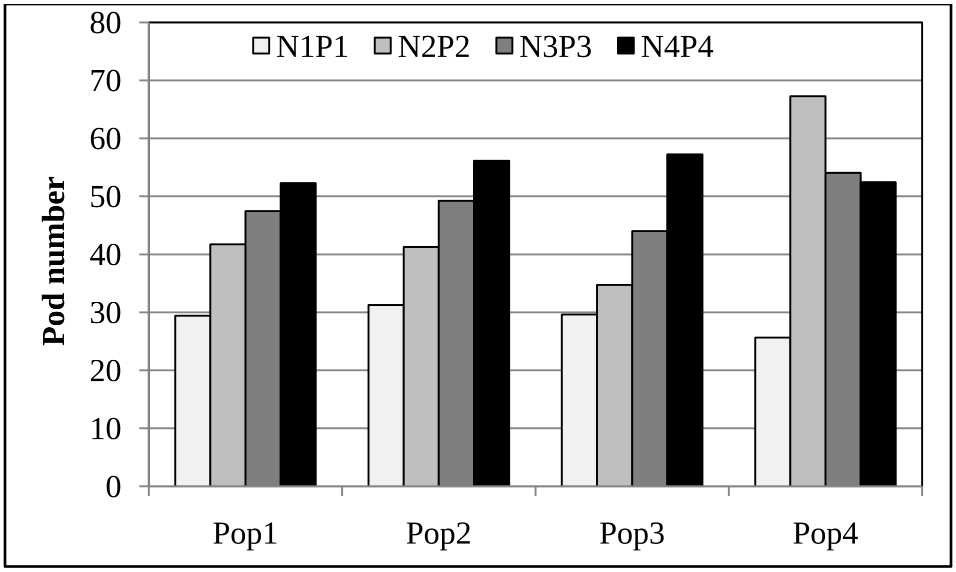

Figure: 2. Effect of plant population and NP fertilizer on Number of pods per plant of Soybean

Plant population/ha

4.3.2. Pod length

The effect of plant population and NP fertilizer on pod length was given in the Table 6 and Appendix Table 3. The effects of plant population, NP fertilizer and their interaction was highly significant (P<0.01), while NP fertilizer showed significant difference at P<0.05 for pod length. The maximum pod length was recorded at the combination of N2P2xPop4 (8.80 cm), while the minimum value was recorded for N1P1xPop1 (3.16 cm). This is because as plant population and NP fertilizer increases the pod length of plant for their role in the containing maximum number of seed. As plant population and NP fertilizer increases; pod length also increasing due to maximum nutrient supplied. The results agree with previous finding ofOgunlela*et al*, (2012) who reportedthat phosphorous level revealed significant effect of pod length. First pod height values varied between15.5 and 21.6 cm (Caliskan*et al.*, 2007).

Table: 6 Interaction effect of plant population and NP fertilizer on Pod length (cm) of Soybean inKersa Woreda of Jimma zone, south western Ethiopia

NP fertilizer	Plant population

	Pop1	Pop2	Pop3	Pop4
N1P1	3.16[f]	3.25[f]	4.10[ef]	3.60[f]
N2P2	5.36[de]	5.50[de]	6.23[bcd]	8.80[a]
N3P3	5.43[de]	5.75[cde]	5.83[cd]	7.26[abc]
N4P4	7.60[ab]	6.73[bcd]	7.53[ab]	5.40[de]
LSD (0.05)	1.66			
CV (%)	16.04			

Means followed by the same letter(s) with in columns and rows are not significantly different at 0.05 probability level.

4.3.2. Number of seeds per pod

The effect of NP fertilizer showed highly significant difference(P<0.01),while plant population and their interaction did not show significant variations for number of seeds per podTable 7 and Appendix Table 3. The maximum number of seeds per pod was recorded for Pop2 (70.49), while the minimum value was observed for Pop4 (61.58). On the other hand, the maximum number of seed per pod resulted for N4P4 (78.13), while the minimum number of seeds per pod for NP fertilizer was recorded at N1P1 (50.75). As NP fertilizer increases number of seeds per pod also increase. This is probably because maximum NP fertilizer can compensate the resource competition. Similarly, at low plant population number of seeds per pod is maximum may be due to low competition and high interception of light. The current study aligns with the Cox and Cherney, (2011) who reported a strong relationship between plant population and seeds per plant. In most legume plants, the number of seeds per pod for any given cultivar is a relatively stable character. In soybean, the number of seeds per pod was slightly affected by the levels of NPfertilization as noticed by Akbari*et al*. (2001).

Table: 7 Effect of plant population and NP fertilizer on number of seed per pod (NS)of Soybean in Kersa Woreda of Jimma zone, south western Ethiopia

Plant population	NS

Pop1	67.85[a]
Pop2	70.49[a]
Pop3	60.42[a]
Pop4	61.58[a]
LSD(0.05)	Ns
NP fertilizer	
N1P1	50.76[c]
N2P2	63.94[b]
N3P3	67.51[ab]
N4P4	78.13[a]
LSD(0.05)	11.97
CV (%)	22.06

Means followed by the same letter(s) with in a column for a given treatment are not significantly different at 5% P level

4.3.3. Hundred Seed weight

The result revealed that plant population, NP fertilizer and their interaction highly significant(P<0.01) for hundred seed weight(Figure 3 and Appendix Table 3). The maximum hundred seed weight was recorded for (N4P4 xPop1) (21.3g), while the minimum value was recorded for N4P4XPop4 (18.50g). The increase in seed weight at higher NP fertilizers especially lower plant populations might be due to availability of more resources. The current result is in contrary with findings of Pedersen, (2008) who found that a seeding rate of 18.5 seeds m^{-2} had a 100-seed wt. of 14.2 g ` and seeding rates of 31.0 to 55.6 seeds m^{-2} had a 100-seed wt. of 14.4 g , but these differences were most likely due to different location conditions.

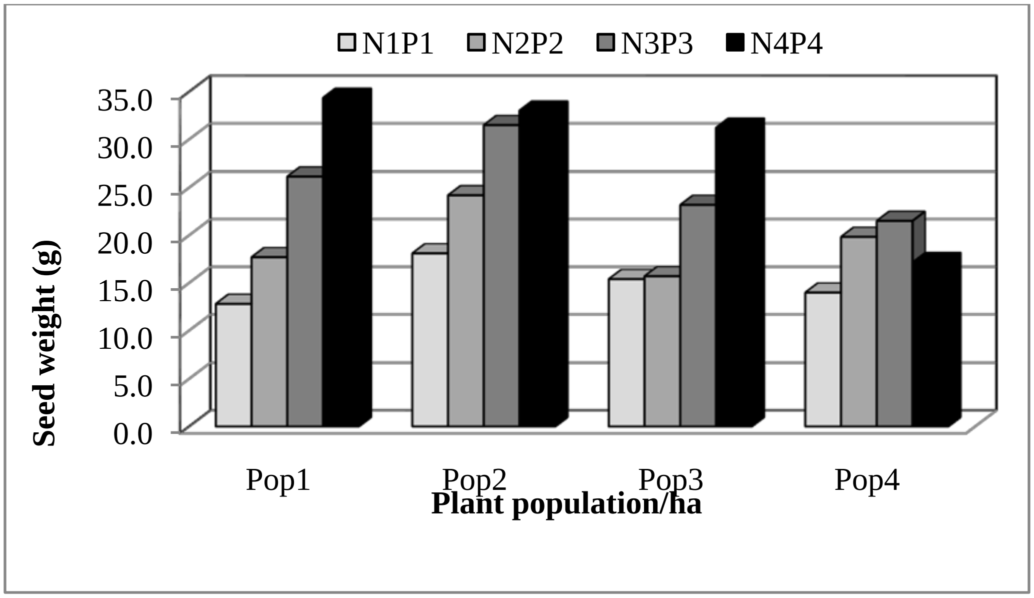

Figure: 3. Effect of plant population and NP fertilizer on hundred seed weight of Soybean

4.3.4. Biomass yield

The analysis of variance revealed that the interaction effects between plant population and NP fertilizer were showed significant difference (P<0.05), while NP fertilizer showeda highly significance difference (P<0.01) and plant population did not showed significance for biomass yieldTable 8 and Appendix Table 3.Maximum biomass yield was recorded for the combination of N2P2x Pop4 is probably (5491.7 kg /ha), while the minimum value was obtained at N1P1 x Pop1 (3075 kg /ha). This is probably because of the biological yield increased by increasing plant density due to higherleaf area, number of branches and plant height. These results are in agreement with the findings of Bullock *et al*, (1998) reported that narrow row spacing or maximum plant population more efficient use of available light and shaded the surface soil more completely during the early part of the growing season while the soil is still moist and, therefore, low population are more effective in producing biomass. In contrary biomass yield per plant decreases progressively as the number of plants in a given increases. This is because the production of individual plant is reduced (Hamidia*et al.*, 2010).

Table: 8. Interaction effect of plant population and NP fertilizer on above ground biomass yield (kg/ha) of Soybean inKersa Woreda of Jimma zone, south western Ethiopia

NP fertilizer	Plant population			
	Pop1	Pop2	Pop3	Pop4
N1P1	3075.0[e]	3616.7[ef]	3733.3[def]	3808.3[cdef]
N2P2	3775.0[cdef]	4000.0[bcde]	4616.7[bc]	5491.7[a]
N3P3	4225.0[bcde]	4216.7[bcde]	3966.7[bcde]	4466.7[bcde]
N4P4	4700.0[ab]	4516.7[bcd]	4483.3[bcd]	4141.7[bcde]
LSD (0.05)	865.24			
CV (%)	12.12			

Means followed by the same letter(s) with in columns and rows are not significantly different at 0.05 probability level.

4.3.5. Grain Yield

The effect of plant population and NPfertilizer on grain yield per hectare was presented in Figure 4 and Appendix Table 3. Statistical analysis of the data revealed that plant population and NP fertilizer showed highly significant effect($P<0.01$), while the interaction between two had significant difference ($P<0.05$) for the grain yield per hectare. The maximum value of grain yield was recorded for the combination of N2P2xPop4 (1960.2 kg/ha), while the minimum grain yield was recorded for N1P1xPop1 (1106.3 kg/ha). The reason for increased grain yield with increasing plant population may be due to increased net crop assimilation rate and more number of plants harvested unit^{-1} areas. The higher grain yield was probably due to higher leaf area, plant height, number of seed per pod and increased biomass yield at higher population. The grain yield increase due to increased rate of NP fertilizer application could be attributed to the improved leaf area development, which increases rate of assimilation by leaves.

This is supported by findings of Edwards and Purcell (2005), which showed that as soybean population increases, yield increases rapidly until it becomes asymptotic per plant. Adequate N supply throughout the growing season has also been shown to be important for high yield (Salvagiotti*et al.*, 2009). Adding 16 kg/ ha N as banded starter fertilizer had a 6% yield increase over the non-treated check (Osborne and Riedell, 2006). On the other hand Haq and Mallarino, (2000) have reported that the response to foliar N-P-K fertilizer application varies based on soil test levels and local weather conditions. Nerveless, it has been reported that nitrogen influenced grain yield through source–sink relationships, resulting in higher rates of photosynthesis and, thus, soybean grain yield increased by 38.7% when application of N increased from 0 kg N/ha to 90 kg N/ha(Asfaw and Angaw, 2003) have observed that application of 120 kg P ha^{-1} in faba bean at Holleta provided three times higher grain yield compared to the control, 0 kg P/ha. Similarly, it has been found that nitrogen rate had no effect on seed yield per plant across all N rates, butincreasing the population reduced yield per plant and increased yield per unit area (Ball *et al.*, 2000).

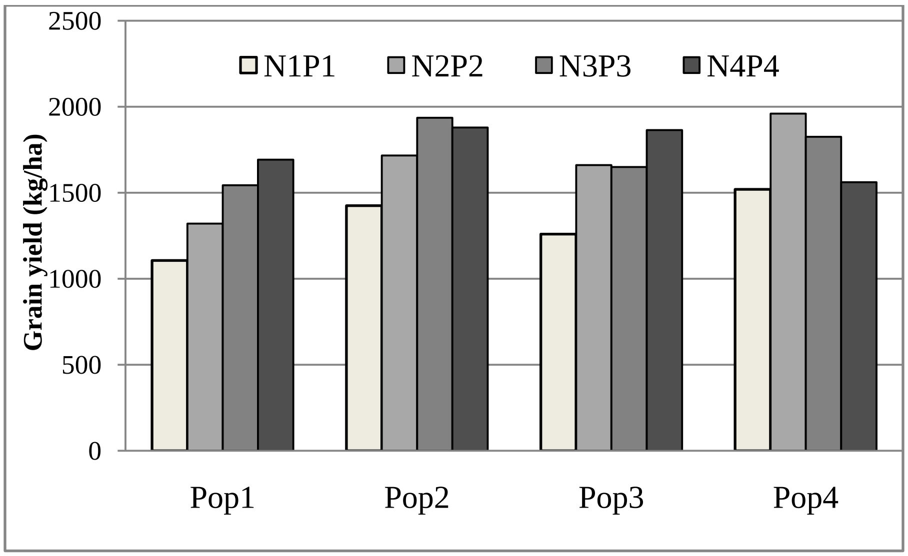

Figure: 4. Effect of plant population and NP fertilizer on grain yield of Soybean

4.3.6. Harvest index

The effects of plant popula vest index were given in Table 9 and Appendix Table 3. The NP fertilizer and their interaction did not show significant variations in harvest index, while NP plant population showed significant difference($P<0.05$). The maximum harvest index was recorded for Pop2 (0.42), while the minimum value was recorded for Pop1 (0.35). Although, it was not significant maximum harvest index for NP fertilizer was recorded at N3P3 (0.40), while the minimum value was observed for N1P1and N1P1 (0.37).

This result shows that harvest index decreased by increasing plant density probably due to the increased competition for resource in high densities. It could also be related with number of branches and total leaf area which are higher in low populations than in high populations. These results agree with the findings ofMalik *et al*. (2006) who reported thatN application has effect on harvest index of soybean. In contrary, these results agree with Board (2000) and Green-Tracewicz (2011) has reported that HI is non-responsive to plant density and stable even after periods of stress throughout plant development.

Table: 9. Effect of plant population and NP fertilizer on harvest index of Soybean in kersa Woreda of Jimma zone, south western Ethiopia

Plant population	HI (%)
Pop1	0.36[b]
Pop2	0.43[a]
Pop3	0.38[b]
Pop4	0.38[ab]
LSD(0.05)	0.04
NP fertilizer	
N1P1	0.37[a]
N2P2	0.37[a]
N3P3	0.41[a]
N4P4	0.39[a]
LSD(0.05)	Ns
CV (%)	12.41

Means followed by the same letter(s) with in a column for a given treatment are not significantly different at 5% P level

4.4. Correlation Analysis

Correlation analysis for growth parameters, yield and yield related traits was presented in Table 10. The simple correlation analysis showed that days to 50% flowering was highly significantly (P<0.01) and positively correlated with number of leaves (r=0.422),number of branches(r=0.457), number of pods per plant (r=0.373) and pod length(r=0.504).Number of leaves per plant has highly significant (P<0.01) and positive correlation with fresh weight (r=0.477), leaf area (r=0.403), days to 50% maturity(r=0.528), number of seeds (r=0.539) and pod length (r=0.376). This shows that these parameters have direct relationship with chlorophyll development and photo-assimilate supply for plant growth and yield.Number of branches was highly significantly (P<0.01) and positively correlated with number of seeds(r=0.404) and pod length(r=0.589). Fresh weight was highly significantly (P<0.01) and positively correlated with dry weight (r=0.661), leaf area (r=0.685), number of pods(r=0.568) and number of seeds(r=0.619). Dry weight has highly significant (P <0.01) and positive correlation with leaf area (r=0.502), and number of pods (r=0.445). Number of nodules was highly significantly (P<0.01) and positively correlated with pod length(r=0.381) and biomass yield (r=0.405). Plant height has also highly significant (P<0.01) and positive correlation with leaf area (r=0.558), biomass yield (r=0.511) and grain yield (r=0.501).This implies that photosynthetic ally active radiation was highly contributed for photosynthesis and plant growth. This observation agreed with the findings of Malik *et al.,* (2011), indicating the correlation coefficients (r) and coefficients of determination (R2) from the correlation and regression analyses of some morphological growth and yield component traits would estimate soybean seed yield.

Leaf area was highly significantly (P<0.01) and positively correlated with number of pods per plant(r=0.436) and number of seeds per pod (r=0.529). Days to 50% maturity was highly significantly (P<0.01) and positively correlated with number of pod per plant (r=0.412).Number of pods per plant was highly significant (P<0.01) and positively correlated with number of seed per pod (r=0.423) and hundred seed weight (r=0.444). Harvest index was highly significant (P <0.01) and positive correlation with biomass yield (r=0.550). Hundred seed weight was significantly (P<0.05) and positively correlated with pod length (r=0.298),which has highly significant (P<0.01) and positive correlation with biomass yield(r=0.386).The relationship between biomass yield and grain yield was highly significant (P<0.01) and positive correlation with grain yield(r=0.922).Thephysiological process during growth and development of plants, chemical contents of pods and other yield components were very high.Plant productivity related with the efficacious plant nutrition with its interaction with other factors of the environment (humidity, temperature, light conditions etc.), any change in the values of each factor results in many other changes. This also in agreement with the findings of Oladajo*et al*. (2011) noted pod weight as one of the agronomic traits that is most appropriate forselection of improved grain yield in cowpea.

Table: 10. Pearson Correlation Coefficients of different growth yield and yield related parameters.

	DF	NL	NB	FW	DW	NN	PH	LA	DM	NP	NS	HI	HS
DF	1												
NL	0.42**	1											
NB	0.45**	0.36*	1										
FW	0.30*	0.47**	0.27	1									
DW	0.28*	0.23	0.18	0.66**	1								
NN	0.24	0.18	0.29*	0.17	0.21	1							
PH	0.06	0.20	0.24	0.30*	0.17	0.27	1						
LA	0.26	0.40**	0.27	0.68**	0.50**	0.19	0.55**	1					
DM	0-.05	0.52**	-0.15	0.22	0.04	-0.01	0.34*	0.19	1				
NP	0.37**	0.69**	0.25	0.56**	0.44**	0.14	0.09	0.43**	0.41**	1			
NS	0.28*	0.53**	0.40**	0.61**	0.36*	0.18	0.24	0.52**	0.24	0.42**	1		
HI	0.01	0.20	0.20	0.06	0.14	0.32*	0.22	0.09	0.08	0.08	0.17	1	
HS	0.10	0.39**	0.28	0.31*	0.12	0.24	0.11	0.26	0.23	0.44**	0.50**	0.29*	
PL	0.50**	0.37**	0.58**	0.27	0.20	0.38**	0.10	0.27	-0.00	0.25	0.35*	0.27	0.29
BM	0.13	0.27	0.31*	0.26	0.17	0.40**	0.51**	0.35*	0.10	0.04	0.14	0.55**	0.23
Gy	0.15	0.16	0.22	0.26	0.16	0.33*	0.50**	0.35*	0.08	-0.01	0.07	0.23	0.11

**. Correlation is highly significant at 0.01 P level (2-tailed). *. Correlation is significant at 0.05 P level (2-tailed).DF=Days to 50% flowering; NL=leaf number ; NB= number of branches; FW=Fresh weight; DW=Dry weight; NN=Number of nodules; PH=plant height; LA= leaf area; DM=Days to 50% maturity; NP=number of pods per plant; NS=number of seed per pod; HS=Hundred seed weight; PL=Pod length; BM=biomass yield and GY=grain yield

4.5. Partial Budget Analysis

The estimated partial budget analysis revealed that economically most advantageous yield of soybean can be obtained with the application of 23/46 kg NP /ha with 400,000 plant population ha,$^{-1}$ which gave the highest MRR, 276 % and 623%, respectively, which is above the minimum acceptable MRR of 100%.This suggests that farmers in Kersa area and its surroundings can profitably produce soybean by applying the given rates. It also shows that blanket recommendation of NP 23/46 kg /hais applicable, while plant population of 333333 plant/ha is no longer advisable for enhancing soybean production in Kersa Woreda (Tables 11 and 12).

Table: 11 Partial budget analysis for yield of Soybean in response to NP fertilizer application

NP rates Kg /ha	Attainable yield kg /ha	Adjusted Yield kg /ha	Gross Benefit Birr /ha	Total Variable Cost Birr /ha	Net Benefit Birr /ha	MRR (%)
23/23	1106.3	995.67	19913.4	0	19913.4	
23/46	1420.2	1278.18	25563.6	1500	24063.6	276%
46/46	1543.4	1389.06	27781.2	2800	24981.2	70%
69/69	1592.0	1432.80	25656	3500	25156.0	24%

The yield was adjusted by 10% adjustment coefficient.

Table 12 Partial budget analysis for yield of Soybean in response to Plant population

Plant population /ha (seed rate kg/ha)	Attainable yield kg /ha	Adjusted Yield kg /ha	Gross Benefit Birr /ha	Total Variable Cost Birr/ha	Net Benefit Birr /ha	MRR(%)
166667(28kg /ha)	1106.3	995.67	19913.4	0	19913.4	
200000(34kg /ha)	1224.3	1101.87	22037.4	1100	20937.4	93%
333333(56kg /ha)	1359.0	1223.1	24462	1500	22962	506%
400000(67kg /ha)	1519.8	1367.82	27356.4	1900	25456.4	623%

The yield was adjusted by 10% adjustment coefficient.

5. SUMMARY AND CONCLUSION

The results of the present study showed that plant population and NP fertilizer rate as well as their interaction had considerable influence on different growth and yield parameters of soybean in the experimental area. Growing soybean with optimum plant population and NP fertilizer could make an important contribution to increase production and productivity of the crop in areas where the use of using inorganic fertilizers and higher plant population is limited. To this end, optimum level plant population and NP fertilizer for soybean could be one of the alternatives to improve productivity by small farmers.

In the present study, it was observed that the interaction of plant population and NP fertilizer significantly influencednumber of branches, number of nodules and number of pods per plant, hundred seed weight, pod length, biomass yield and grain yield. The highest number of nodules(8.66), hundred seed weight(21.3g), number of branches (8.06), number of pods per plant (67.26), pod length (8.80 cm), biomass yield (5491.7 kg/ha) and grain yield(1960.2 kg/ha,) were recorded from 400000 plant/ha plant population and 23/46 kg/ha NP fertilizer while the lowest, number of nodules(3.36), hundred seed weight(21.3g), number of branches (2.26), number of pod per plant (25.66) and pod length (3.16) biomass yield(3075 kg/ha), and grain yield(1106.3 kg/ha) were recorded from 166667 plant/ha plant population and 23/23 kg/ha NP fertilizer. It was also observed that the effect of plant population and NP fertilizer have significant effects on days to 50% flowering, days to 50% maturity, leaf area, plant height, number of leaves, leaf fresh weight, leaf dry weight, number of seeds per pod and harvest index.

Accordingly, it was also noted that among the yield components, increase in number of pod per plant and number of seed per pod were responsible for the observed yield advantage. In contrast, application of NP and plant population did not have considerable effect on number of branches, number of nodules, hundred seed weight and pod length. In general, optimum plant population and NP fertilizer rate were effective in improving growth, yield, economic benefits, production and productivity of soybean.

Increased the rate NP fertilizer from 23/46 kg/ha to 69/69 kg/hasignificantly increased days to 50% flowering and days to 50% physiological maturity. Similarly, at lower plant population significantly it decreased days to 50 % flowering. The combined effect of 69 kg of NP/ha and 400,000 plants/haincreased plant height, number of pods and total biomass yield, but significantly decrease dry matter content of leaves.

The correlation analysis also showed that the positive relationship between growth and yield parameters were highly for the higher yield in the biomass yield and grain yield. Both growth and yield parameters were highly and positively correlated on each other. Results of this experiment indicated significant differences in grain yield and biomass yield per ha. The highest grain yield and biomass yield per hectare was recorded due to the combination of 46/46 kg/ ha NP fertilizer and 166667 plant population per ha, but grain yield for 23/46 NP fertilizer and 333,333 plants/ha was also statistically comparable.

These results generally suggested that applying NP fertilizer at a rate of 23/46 kg/hacan give higher yield of soybean in Kersa area under normal growing conditions. This was supported by a partial budget analysis where application of 23/46 kg/ha NP fertilizer and plant population of 400,000 plant /ha gave the highest MRR, of 276 % and 623%, respectively, which is above the minimum acceptable MRR of 100%, suggesting that farmers in Kersa area and its surroundings can profitably produce soybean by applying the given rates. This shows that blanket recommendation of NP 23/46 kg /ha isapplicable, while plant population of 333333 plants/hais no longer advisable for enhancing soybean production in Kersa Woreda.

In conclusion, the present study reveals that soybean seed yield depends on plant population and NP fertilizer rate. Crop dry matter accumulation and leaf area showed significant positive relationship with seed yield**.** In the present trial, the highest soybean yield was achieved at 23/46 kg/ha NP fertilizer and plant population of 400,000 plant /ha which was recommended for the Kersa areas who produce soybean.

Nonetheless, it is too early to arrive at a conclusive recommendation since the experiment was conducted only with one variety at a single location for one season. Hence, future studies that consider varying, season, location, soil types and different fertilizers and plant populations with a detail cost-benefit analysis are needed to develop optimal fertilizer recommendations for increased production and productivity of soybean in Southwestern part of Ethiopia.

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7. APPENDIX

Appendix Table 1. Summary of soil Lab results for the experimental field

Soil property	
Particle size distribution % and textural class	
Sand	23
Clay	57
Silt	20
Chemical soil property	
pH	4.25
Total N(%)	0.18
OM(%)	3.01
P (ppm)	4
CEC(me/100g)	20.5

N=Total Nitrogen, OM=Organic Matter, P=Available Phosphorus, CEC(me/100g) cation exchange capacity

Appendix Table 2: Preliminary ANOVA for response of soybean to the combined treatment in a RCBD with three replications

Variable	Source of variation		
	Replication	**Treatment**	**Error**
Degree of freedom	2	15	30
Days to flower	72.66	206.53**	15.40
Leaf number	169.24	233.21**	29.00
Branch number	0.8	9.63**	0.84
Fresh Wt	1632.44	208.47**	57.19
Dry Wt	13.18	5.94NS	3.53
Node number	9.69	6.65**	1.09
Plant height	11.41	137.41NS	96.66
Leaf area	4371.26	774.66**	189.82
Days to maturity	219.34	401.17**	47.67
Number of Pod	66.04	430.52**	45.58
Number of seed	845.28	388.55NS	206.27
100-seed weight	81.31	153.30**	12.18
Pod length	3.379	8.020**	0.843
Biomass	480638	918347.22**	256651.91
Grain Yield	23034.16	188733.66**	27662.89
Harvest Index	0.007	0.004NS	0.002

***** highly significant (P< 0.001), ** highly significant (P<0.01), ***Significant (P< 0.05), Ns = non-significant difference,

Appendix Table 3: Summary of ANOVA for soybean growth variables in 4 x 4 factorial experiment involving four levels of plant population and NP fertilizer in a RCBD with three replications

Plant variable	Source of variations					
	Replication	**Treatment**	**Pop**	**NP**	**Pop x NP**	**Error**
Degree of freedom	2	15	3	3	9	30
Days to flower	72.66	206.53**	15.14NS	1005.21**	4.10NS	15.40
Days to maturity	219.34	401.17**	595.47**	1149.86**	86.85NS	47.67
Plant height	11.41	137.41NS	38.86NS	378.90*	89.76NS	96.66
Number of branch	0.8	9.63**	4.11**	35.65**	2.80**	0.84
Leaf number	169.24	233.21**	98.91*	1000.93**	22.06NS	29.00
Leaf area	4371.26	774.66**	1355.07**	1867.49**	216.91NS	189.82
Leaf fresh weight	1632.44	208.47**	648.80**	21.02NS	120.85NS	57.19
Leaf dry weight	13.18	5.94NS	20.44**	0.09NS	3.05NS	3.53
Number of nodule	9.69	6.65**	1.92NS	23.34**	2.66*	1.09
Number of pod	66.04	430.52**	165.59*	1444.76**	180.76**	45.58
Pod length	3.379	8.020**	2.47*	26.78**	3.62**	0.843
Number of seed	845.28	388.55NS	283.73NS	1530.77**	42.74NS	206.27
Seed weight	81.31	153.30**	151.32**	464.10**	50.37**	12.18
Biomass yield	480638	918347.22**	611979.17NS	2204618.06**	591712.96*	256651.91
Grain yield	23034.16	188733.66**	261851.82**	473660.31**	69385.38*	27662.89
Harvest index	0.0068	0.004NS	0.009*	0.004NS	0.002NS	0.002

******* highly significant (P< 0.001), ** highly significant (P<0.01), ***Significant (P< 0.05), Ns = non-significant difference,