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Response of Soybean (*Glycine max* (L) Merrill) to Plant Population and NP Fertilizer in Kersa Woreda of Jimma Zone, South Western Ethiopia

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Abstract

Declining soil fertility status and poor agronomic practices, including minimum use of inorganic fertilizers and inappropriate plant population are the major reasons for low productivity 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. Four levels of NP fertilizer (23/23, 23/46, 46/46 and 69/69 kg/ha) and plant population (166667, 200000, 33333 and 400000 plants/ha) were laid out in a factorial experiment in randomized complete block design with three replications. The analysis of variance also showed that the interaction effects of plant population and NP fertilizer were significant on number of pods, pod length, number of nodules, hundred seed weight, biomass yield and grain yield. Whereas plant population had significant influences on days to 50% flowering, days to 50% maturity, number of branch, number of nodules, plant height, leaf area, number of pods, number of seed per pod, hundred seed weight, biomass yield, and grain yield. Likewise, the main effects of NP fertilizer was significant on number of pods, number of branches, number of leaves, leaf area, plant height, days to maturity, 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 the same a combination of plant population and NP fertilizer.

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Keywords

Soybean production, soil fertility management, plant nutrients, land productivity and profitability

Introduction

Soybean (*Glycine max (L.) Merrill)* is an important legume crop, which grows in the tropical, subtropical and temperate climates (Shurtleff and Aoyagi, 2007). It is the leading oil and protein crop of the world, which used as a source of high quality edible oil, protein, and livestock feed (Rajcan *et al.*, 2005). It is a leading source of edible vegetable oil and protein for both humans and animals, has the potential to nourish humans worldwide in the near and distant future (Hartman *et al.*, 2011). The balanced combination of protein, fat and carbohydrates of soybean products were 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 actual potential land only about 7% of favorable land allocated to soybeans, SSA 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 major advantages in sustainable cropping systems (Sinclair and Vadez, 2012), including an ability to fix atmospheric nitrogen (N_2) via symbiotic N_2fixation and, hence, alleviate the need to apply large amounts of nitrogen fertilizer. 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). About 6.8 million households, representing about 28.6 million people in SSA, grow soybean. 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 total area nationally covered by soybean crop, about (35,259.76 ha) and a total production 721,837.45 qt with a productivity of 20.47 qt/ha (CSA, 2015). Some of the constraint shown by studies (Shumba-Mnyulwa, 1996) carried out on smallholder soybean production include low plant population, lack of access to Brady rhizobium japonicum, use of unimproved varieties, unavailability of certified seed and use of retained seed and general lack of knowledge on the recommended agronomic practices in soybean. Soil acidity can limit the survival and growth of Rhizobia in soil and can also affect the process of nodulation and N_2 fixation. Soil pH, generally at values less than 5.5 to 6.0, can drastically affect rhizobial infection, root growth, and legume productivity (Havlin *et al.,* 2005). The pH range 6.0 - 7.0 is considered to be suitable for rhizobial growth (Hungria and Vargas, 2000). This is attributed mainly to the limited extension and research in soybean in the smallholder sector (Mabika and Mariga, 1996). Plant population is an important component of yield in soybean and 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) 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 maturiting varieties are used (Ball *et al.,* 2000). Increased seed rate will influence yield to a point, however, 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 RS decreased, but it did not identify optimum plant density for high yield, nodulation and weed control.

The national average yield of soybean varied from 1.8 t/ha (2012) to 2 t/ha (2013) while the potential yield at research and farmers' field are 3.5 and 2.6 t/ha (MARD, 2012), respectively. In spite of this many biotic and a biotic factors contribute to the low yield of these nitrogen and phosphorus are the main factors that significantly reduce the production and productivity of legume crops (Kamara *et al.*, 2007; Tahir *et al.*, 2009). Soil acidity associated soil fertility problem is one of the most important soybean production constraints in several countries, for example in Western Ethiopia (Tesfaye *et al.,* 2011), where most soils are characterized by moderate to strong acidity (van Straaten, 2002).

The low availability of phosphorus nutrition in soils has become the limiting factor for plant and root growth (Zafar *et al.*, 2013). Phosphorus has a key role in the energy metabolism of all plant cells and particularly in nitrogen fixation as an energy requiring process (Jones *et* *al.,* 1977). Legume plants that depend on biological N_2 fixation for their N supply require more P and other macro and micro nutrients than plants receiving fertilizer N 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 to infertile soil is recognized to be a quick and direct way of boosting crop production (Tarekegne and Tanner, 2001). Yield of legumes in farmers' field is usually less than 0.65 t/ha against the potential yield of 1.2t/ha suggesting a large yield gap (CACC; 2002) and low yield potential of legumes has made them less competitive with cereals and other high value crops. The use of leguminous crops for this inert nitrogen fixation and incorporation into agricultural soil is getting prime importance in Ethiopian context (Wmeskel, 2007; Bekere and Hailemariam, 2012; Bekere *et al.,* 2013). In western Ethiopia, soybean reached a peak yield of 2406.7 kg/ha with application of 46 kg P_2O_5/ha, but higher concentration of fertilizer produced lower yields as the evidence is observed compare with 57.5 kg P_2O_5/ha found in DAP (Desta, 1986). The low productivity of the crop is due to several constraints, one among the unbalanced important nutrition (Sharma *et al.*, 1996) and plant population. The NP fertilizer where applied as the corresponding or without separation in the crop production field is 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 and needs high amount of energy for N fixation and it is difficult fix N by soybean plant. 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). N fixation alone cannot meet the N requirement for maximizing soybean yield. 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).

This has 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, the 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 objectives to evaluate the response of soybean to plant population and NP fertilizer in Kersa woreda of Jimma zone, south western Ethiopia.

Materials and Methods

Description of the Study Area

The study was conducted at Kersa woreda of the Jimma Zone South western Ethiopia under rain fed conditions during the main cropping season in 2015/2016. The site is located at about 318 km from Addis ababa and 28 km East from Jimma town (7° 40′ 0″ N latitude and 36° 50′ 0″ E longitude) at an alttitude 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 *et al., (*2011), the major reference soil groups in the Gilgel-Gibe catchment are Nitisols, 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).

Treatment combinations (4x4)

NP fertilizer- = 23/23 kg/ha, 23/46 46/46, and 69/69 Kg/ha, and coded as N1P1, N2P2, N3P3 and N4P4, respectively. Whereas N was split applied after thinning, while DAP was drilled along seed line at time of planting. Plant population levels = 166,667, 200000, 333333 and 400000 (Plant /ha) also coded as Pop1, Pop2, Pop3 and Pop4, respectively. A 4 x 4 treatment combinations were studied under on-farm conditions. The released and locally dominant under production soybean variety- Clark- 63 K was used for the study to evaluate plant responses and identify the best treatment interactions. The experiment was carried out in factorial experiment arranged in a RCBD with three replications. Thus, there were a total of 16 treatments used for the experiment. The experimental field of consisted forty-eight plots. Gross plot size was 5m x 4m (20 m^2) accommodating 6 rows of each and the distances between plot and block were 0.8m and 1 m, respectively leaving the outer most rows on both sides of each plot to avoid border effects.

Experimental Procedures and Crop Management

The land was prepared on the farmer's field by removing all unwanted materials. Before sowing the crop and the field was plowed with oxen two to three times to make a fine seed bed. The source of N and P was urea and DAP) respectively. Under research, 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.

Soil sampling and analysis

A composite 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 lab for the major selected physico-chemical properties.

These includes, soil pH, organic carbon, total N, available phosphorus and cation exchange capacity (CEC) using standard laboratory procedures. Total N in the soil was determined by the Kjeldahl digestion, distillation and titration method (Dewis and Freitas, 1975). Available phosphorus was determined using Bray I extraction method as described by Van Reeuwijk, (1992) and extraction with 0.5M NaHCO3 (Olsen *et al.*, 1954).

Organic carbon content of the soil was determined by reduction of potassium dichromate by organic carbon compound and determined by reduction of potassium dichromate by oxidation reduction titration with ferrous ammonium sulfate and organic carbon was determined by the method of Nelsen and Sommers, (1982). Particle size distribution was determined by hydrometer method (differential settling within a water column) using particles less than 2 mm diameter (FAO, 2008) and texture of the soil was determined by sedimentation method (Hesse, 1971). Phosphorus in the extracts was determined with atomic absorption spectrophotometry calorimetrically according to the molybdenum blue color method described by Murphy and Riley, (1962)

Data collected

Growth parameters

Days to 50% flowering

It were determined by observing the plants in each plot when 50% of the plant in the plot start to flower.

Days to 50% maturity

It was record from planting time to when 50% of plants formed a color change from the lower part of the plant to the upper part. These was when plants shows a color change by half and it is expected to harvest after 45 days.

Number of nodules

It was determined as the total number of nodules per plant recorded at 50% days to flowering from 5 randomly selected plants per plot.

Number of leaves per plant

It was determined as the total number of leaves and at flowering and at physiological maturity from 5 randomly selected plants per plot.

Number of branches per plant

The number of branch was estimated by counting the branches from 5 randomly selected plants from each plot at maturity.

Leaf area

It was measured from five plants, which were randomly taken from the two border rows with leaf area meter (LI-3100C leaf area meter).

Plant height

It was measured by centimeters from the ground level to the top of the plant at flowering and at physiological maturity from 5 randomly selected plants from each plot.

Fresh weight

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

Dry weight

It was measured from five randomly taken mature plant leaves from each plot and oven drying at 70^{o}C until constant weight is attained. 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

Yield and yield components

Number of pods per plant

The number of pods was counted from five randomly selected plants of the two middle rows at the time of harvesting from each plot by visual observation and their averages were recorded.

Number of seeds per pod

It was determined as the total number of seeds per pod in each plot at the time of harvesting from the five randomly selected plants.

Pod length (cm)

It was measured at harvesting from 5 randomly selected plants and the average is 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. One of the most important steps in soybean preparation is the drying process. After the harvest, soybeans must be dried to levels between 10% and 13% (wet basis) of the MC (moisture content), which is achieved by processing the soybeans in a dryer. MC= Mw/Wd

Where, MCDB is the moisture content of the sample in dry basis, mw is the mass of water contained in the soybeans and md is the dry mass of the sample

Biomass yield (kg/ha)

Plants from the net plot area were harvested at physiological maturity, seeds were removed and only dry stems were weighed after plants dry.

Grain yield (kg/ha)

It was measured from each plot and converted into hectare basis.

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 biomass yield

Stastical analysis

The collected data were summarized and statistically analyzed using the Analysis of Variance (ANOVA) procedure for factorial experiment in a RCBD using SAS software (SAS, 2002). Tretament means that differed significantly were separated by using the LSD procedure at 5% level of significance. Correlation coefficient was determined for parameters using the same software.

Results and Discussion

Soil physico-chemical characteristics

The laboratory results of after harvesting of selected physical and chemical analysis of the experimental soil are presented in Appendix Table 1. Soil analysis after harvesting in the experimental field has shown that the soil had clay texture with a clay content of 57% and a soil pH of 5.3 which was rated as moderately acidic Tekalign, (1991). Soil organic matter of the experimental site was low 3.23%. The low organic matter might be attributed to the intensive cultivation and continuous removal of crop residues through animal feeding. The analysis further indicated that the soil had low total nitrogen 0.23% and available phosphorus 10.20 ppm according to the ratings of Tekalign, (1991) and Marx *et al.*, (1996), respectively. The cation exchange capacity of 21.28. The low nitrogen content could be accompanied with the low soil organic matter content. The low available P was probably ascribed to the high P sorption caused by presence of calcium carbonate. The soil analysis in general indicates that the soil physio-chemical properities increased after harvesting. This might be due to the contribution of applied fertilizers and the rotation crops from soghum to soybean which can increase the organic materr content of the soil.

Phenological Growth Parameters

Days to 50% Flowering

The main effect of plant population and NP fertilizer on days to 50% flowering were given in Table 2 and Appendix Table 3. Plant population were shows significant at p<0.05, while the interaction between plant population and NP fertilizer and NP fertilizer did not show significant variations on days to 50% flowering. The maximum days to 50% flowering of population were recorded at Pop3 (61.51), while minimum days to 50% flowering were recorded at Pop2 (58.87). The maximum days to 50% flowering of NP fertilizer were recorded at N4P4 (71.99), while minimum days to 50% flowering of NP fertilizer were recorded at N1P1 (50.85). It is due to the maximum plant population prolog the flowering stage of soybean due to the low availability of nutrient, light and moisture. The current study agreed with the previous (Brady and Weil, 2002) stated that phosphorous is helpful in flowering and hastens maturity of crops if in single application 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. This concurred with Wood *et al.*, (1993) in that the application of N fertilizer significantly delayed physiological maturity of soybean.

Days to 50% maturity

The main effect of plant population and NP fertilizer shows significant effect at P<0.01, while the interaction between plant population and NP fertilizer did not show significant effect on days to 50% physiological maturity which were given in the Table 2 and Appendix Table 3. The maximum value of days to 50% maturity in plant population were recorded at Pop2 (124.15), while minimum value were recorded at Pop4 (107.54). The maximum value of days to 50% maturity of NP fertilizer were recorded at N4P4 (127.22), while minimum value were found at N1P1 (106.41). This could be due to the fact that the maximum plant population matured earilier due to competition for nutrient, light and moisture, while in the lower plant population stay vegetative growth and at high NP fertilizer matured later, because of high resources plants stay vegetatively growth rather than mature. The current study agreed with that of Wood *et al.*, (1993) who reported that application of N fertilizer significantly delayed physiological maturity of soybean.

Vegetative growth and root nodule

Plant height

The analysis of variance of plant population and NP fertilizer on plant height given in Table 2 and Appendix Table 3. Statistical analysis of the data revealed that the main effect of NP fertilizer and interaction of plant population and NP fertilizer were non-significant, while plant population were significant at P<0.05. The maximum plant height of plant population were recorded at Pop1 (48.23), were as the minimum plant height were recorded at Pop4 (44.39). The maximum plant height of NP fertilizer were recorded at N4P4 (52.55), but minimum value were recorded at N1P1 (38.81). These indicates that as plant population and NP fertilizer increase plant height also increases, which creates lodging problems, low branching and low pod per plant. This indicates that the competition among the plants for nutrients uptake and sunlight interception also increased. This experiment was in agreement with 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). The greater plant height for the growth periods (Staggenborg *et al.*, 1996) reported significant increase in soybean plant height in wider row spacing of 30-inch as against narrow row spacing of 18-inch, at high-yielding environments. This result is in harmony with that of Kayhan *et al.*, (1999), who reported increase in plant height, leaf area index and light interception due to increased plant density in soybean and could be attributed to consequences of infrastructure development within and between plant communities.

Number of leaves per plant

The main effect of plant population and NP fertilizer shows significant at P<0.01 and p<0.05 respectively, while the interaction did not show any significant difference on number of leaves which is given in Table 3 and Appendix Table 3. The maximum number leaves were produced at Pop1 (75.39) of plant population, while the minimum was recorded at Pop3 (69.20). The maximum leaf number for NP fertilizer were recoreded at N4P4 (83.07), while the minimum leaf number were recorded at N1P1 (61.92). Number of leaves reduced with higher plant population, and this is due to competition for assimilates, sunlight, moisture and nutrients and the NP fertilizer consumed due to high population. The current experiment was aligned with Akbari *et al.,* (2001) who reported that depicted increased levels of nitrogen fertilization increased the mean number of leaves per plant. However, Xuewen, (1990) also showed that different nitrogen levels had slight influence on mean number of leaves per plant.

Leaf area

Statistical analysis of the data revealed that the interaction of plant population and NP fertilizer were non-significant, while the main effect of NP fertilizer and plant population was significant at P<0.01 which is given in the Table 3 and Appendix Table 3. The maximum leaf area for plant population were recorded at POP1 (174.04), while minimum value of leaf area were recorded at POP4 (149.27). The maximum value of leaf area for NP fertilizer were recorded at N4P4 (180.47), while minimum value in NP fertilizer were recorded at N1P1 (150.47). This is because of the effect of the plant competition for resources like, space, moisture, sunlight and nutrients at higher plant population and lower fertilizer. This experiment was in agree with Harder *et al.,* (2007) increasing plant population increases LA until the later reproductive stages. Yield increases can be attributed to a greater leaf area index (LA) in narrow compared to wide rows. NPK (15:15:15) plot gave higher leaf area followed by poultry manure probably because of their capacity to release nutrients to plants faster due to higher N content and lower C:N ratio (Awodinn, 2007).

Fresh weight

Data regarding the effect of plant population and NP fertilizer on fresh weight was given in Table 3 and Appendix Table 3. Statistical analysis of the data revealed that plant population and the interaction of plant population and NP fertilizer were non-significant, while the main effect NP fertilizer was significant at P<0.01. The maximum fresh weight for plant population were rcorded at Pop1 (41.84), while the minimum value were recorded at Pop4 (27.87). The maximum fresh weight for NP fertilizer were rcorded at N3P3 (36.10), while the minimum value in NP fertilizer were recorded at N4P4 (33.20). This because of the fresh weight is directly related with phothosyhensis and its assimilate for the chloroplast and the growth facilitation of the plant with respect to vegetative growth. The current experiment aligned with the studies of Rahman *et al.,* (2004) who reported that as the plant growth and yield components increased at lower densities, per unit area yield decreased as a result of less per unit area canopy 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).

Dry weight

The result of plant population and NP fertilizer on dry weight were given in the Table 3 and Appendix Table 3. The interaction of plant population and NP fertilizer were non-significant, while the main effect of NP fertilizer was significant at P<0.05. The maximum dry weight of plant population were recorded at Pop1 (9.10), while minimum dry weight were recorded at Pop4 (6.85). The maximum dry weight of NP fertilizer were recorded at N1P1 (7.87), while minimum value were recorded at N2P2 (7.65). This because of the 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 Taylor 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. Soybean having the highest dry matter yield in NPK plot might be because of NPK's easy dissolvability and absolve ability, which enhanced quick up take for proper growth and development of the soybean plant. However, Ebie and Ayolagha, (2006) also observed that poultry manure gave the highest dry matter of by application of NPK.

Number of branches per plant

Analysis of variance for plant population and NP fertilizer on number of branches were given in Table 4 and Appendix Table 3. The data of plant population and NP fertilizer and their interaction were shown significant, at P <0.05 for NP fertilizer and interaction while plant population at p<0.01. The maximum number of braches were recoreded at N2P2xPop4 (8.06) as opposed to minimum number of branch were recorded at N1P1xPOP1 (2.26). This was due to as plant population increases number of branches per plant decreases. It is because of completion for nutrient, light, moisture and space. This study agree with Boquet, (1990) who reported that increasing plant population plants m^{-2} resulted in decreased number of branches per plant, and decreased the number of pods per plant. Branching typically occurs at low plant populations in order to maximize yield (Carpenter and Board, 1997).

Number of nodules

The results of analysis of variance revealed that plant population and NP fertilizer on number of nodules was given in Table 5 and Appendix Table 3. The main effect of plant population shows significant at P<0.01, while the interaction of plant population and NP fertilizer shows significant at P<0.05. Were as the main effect NP fertilizer was non-significant. The maximum number nodules were recorded at N3P3xPop4 (8.66), while the minimum number of nodules were recoreded at N1P1xpop (3.36).

This is because the soil of the experimental area where highly affect by acidic and could not fix any environmental nitrogen through rhizobium bacteria which facilitates low number of nodules at minimum fertilizer which contradicting one another. This study agree with Giller, (2001) who reported that the application of phosphorous is improves root development, providing more infection sites for rhizobia, hence encouraging nodulation.

Reproductive growth- Yield and yield components

Number of pods per plant

Analysis of variance for plant population and NP fertilizer on number of pod per plant were given in the Figure 2 and Appendix Table 3. Statistical analysis revealed that interaction and plant population shows significant at p<0.05, while NP fertilizer also show significant difference at P <0.01. The maximum number of podper plant was recorded at combination of N2P2x POP4 (67.26). Furthermore, the minimum number of pod per plant were recorded at N1P1xpop4 (25.66). This is due to availability of more resources increase in number of pod per plant to plants on account of low population density. This result also agrees with Lueschen and Hicks, (1977) 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. Similarly, results were reported in peanuts Phakamas *et al.,* (2008) and in chickpeas Ali and Tahir, (1999). Increasing levels of nitrogen fertilization increased the number of pods per plant as indicated by Tola, (1995).

Pod length

The effect of plant population and NP fertilizer on pod length was given in the Table 6 and Appendix Table 3. The main effect of plant population and interaction of plant population and NP fertilizer, were show significant effect at P<0.01, while NP fertilizer also shown significant difference at p<0.05 on pod length. The maximum pod length were recorded at the combination of N2P2xPop4 (8.80), while minimum pod length were recorded at N1P1xPop1 (3.16). This is because as plant population and NP fertilizer increases the pod length of plant for their role in the development of inter node and growth facilitation. Lowest pod height was significantly affected by nitrogen rate and plant density due tgo competition for resources like moisture, light and nutrients. If they decreases it invites loss of yields during harvesting due to nearer to the soil and dwarf of the plant. The results agree with previous finding, Ogunlela *et al.*, (2012) who reported phosphorous level revealed significant effect of pod height. First pod height values varied between15.5 and 21.6 cm Caliskan *et al.,* (2007).

Pods too close to the soil surface increase harvest losses since some combine harvester heads are unable to pick up the first pods (Caliskan *et al.*, 2007). Nitrogen applied at 90 kg/ha resulted in maximum lowest pod height (14.1 cm) compared to the minimum (11.4 cm) in control.

Number of seeds per pod

The main effect of plant population and NP fertilizer on number of seed per pod were given in Table 7 and Appendix Table 3. Plant population shows significant at p<0.01, while NP fertilizer and the interaction between plant population and NP fertilizer did not show significant variations on number of seeds per pod. The maximum number of seed per pod of population recorded at Pop2 (70.49), while minimum number of seed per pod were recorded at Pop4 (61.58).

Fig.1 Effect of plant population and NP fertilizer on Number of pods of Soybean

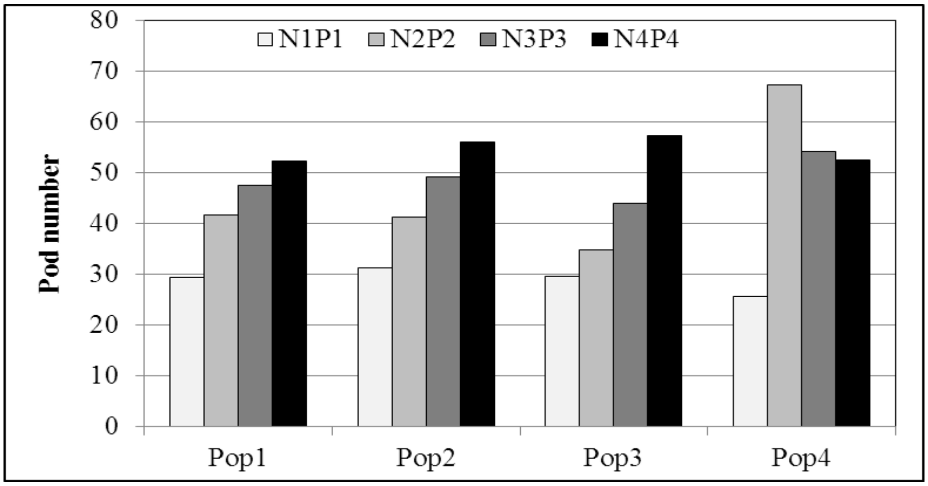

Fig.2 Effect of plant population and NP fertilizer on hundred seed weight of Soybean

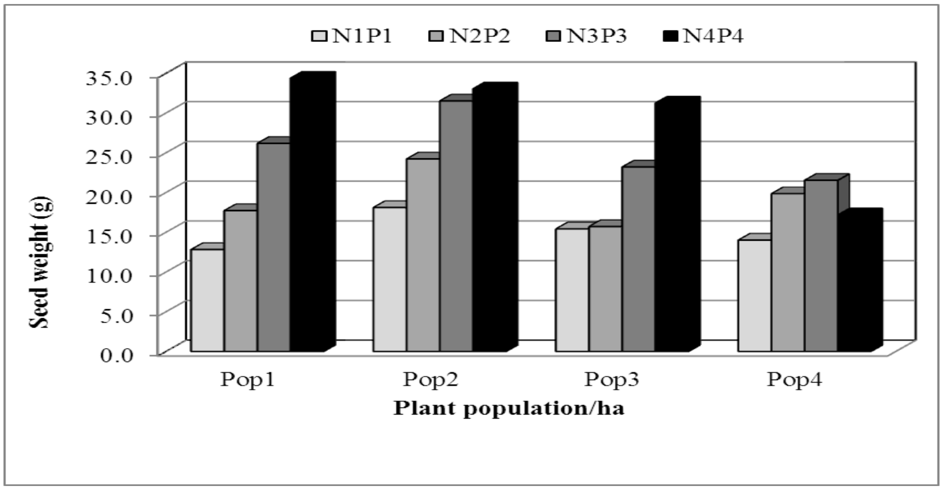

Fig.3 Effect of plant population and NP fertilizer on grain yield of Soybean

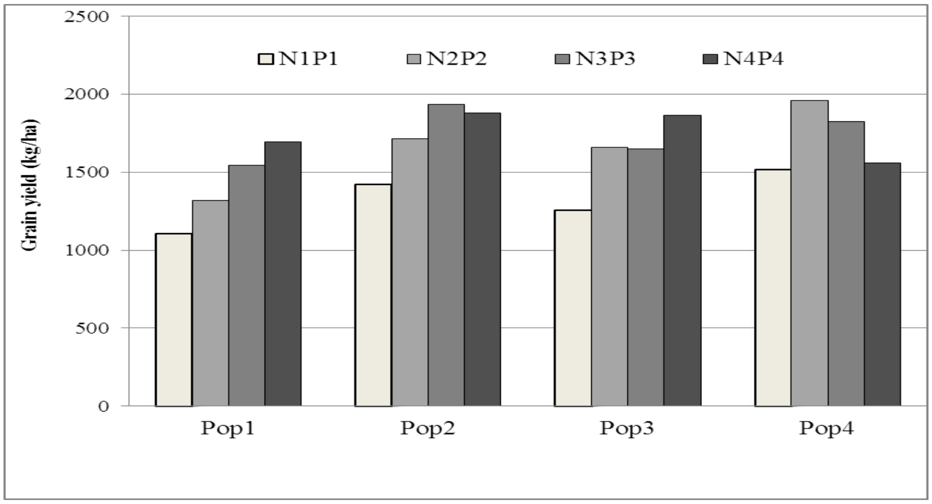

Table.1 Description of the variety

Name of variety	Adaptation area		Yield (t/ha)		Year of release	Breeder/ Center	Maturity days	Oil cont	Seed rate
	Altitude (m)	Rain fall (mm)	RM	FM					
Clark-63K	300-1800	460-1500	15-25	9-11	1982	HARC	121-150	27.9	60 kg

Source; (EARO, 2004) RM=Under research field management, FM=Under farmers field management.

Table.2 Effect of plant population and NPfertilizer on days to 50% flowering and Days to 50% maturity of Soybean at 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[b]
N2P2	55.37[b]	110.27[b]
N3P3	61.55[c]	122.15[a]
N4P4	71.99[d]	127.23[a]
LSD(0.05)	3.27	5.75
CV (%)	6.54	5.92

Means followed by the same letter(s) are not significantly different at 5% p level

Table.3 Main effect of plant population and NP fertilizer on Plant height, Leaf area, number of leaves, fresh weight and Dry weight of Soybean at kersa woreda of Jimma zone, south western Ethiopia

Plant population	PH	NL	LA	FW	DW
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	6.31	ns
CV (%)	21.44	7.46	8.42	21.90	24.23

Means followed by the same letter(s) are not significantly different at 5% p level

Table.4 Interaction effect of plant population and NP fertilizer on Number of branch of Soybean at kersa 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			

LSD = Least Significant Difference; CV = Coefficient of Variation; NPf = NPfertilizer; Pop = Plant population; Values following by the same letter within the column or row are not significantly different at 0.05 probability level.

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			

LSD = Least Significant Difference; CV = Coefficient of Variation; NP fert = NPfertilizer; Pop = Plant population; Values following by the same letter within the column or row are not significantly different at 0.05 probability level.

Table.6 Interaction effect of plant population and NP fertilizer on Pod length of Soybean at kersa woreda of Jimma zone, south western Ethiopia

NPf	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			

LSD = Least Significant Difference; CV = Coefficient of Variation; NPf = NPfertilizer; Pop = Plant population; Values following by the same letter within the column or row are not significantly different at 0.05 probability level.

Table.7 Main effect of plant population and NP fertilizer on number of seed per pod of Soybean at 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
NPfertilizer	
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) are not significantly different at 5% p level

Table.8 Interaction effect of plant population and NP fertilizer on Biomass yield of Soybean at kersa woreda of Jimma zone, south western Ethiopia

NPf	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 (%)	12.12828			

LSD = Least Significant Difference; CV = Coefficient of Variation; NPf = NPfertilizer; Pop = Plant population; Values following by the same letter within the column or row are not significantly different at 0.05 probability level.

Table.9 Main effect of plant population and NP fertilizer on harvest index of Soybean at kersa woreda of Jimma zone, south western Ethiopia

Plant population	HI
Pop1	0.36[b]
Pop2	0.43[a]
Pop3	0.38[b]
Pop4	0.3[8ab]
LSD(0.05)	0.04
NPfertilizer	
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) are not significantly different at 5% p level

Table.10 Pearson Correlation Coefficients of different growth, yield and yield component parameters

	DF	NL	NB	FW	DW	NN	PH	LA	DM	NP	NS	HI	HS	PL	BM	Gy
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*	1			
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*	1		
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	0.38**	1	
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	0.31*	0.92**	1

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

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,

The maximum number of seed per pod of NP fertilizer were recorded at N4P4 (78.13), while minimum number of seed per pod in NP fertilizer were recorded at N1P1 (50.75). This is because at maximum NP fertilizer in the experimental plot can compensate the resource competition and at low plant population number of seed is maximum may 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 nitrogen fertilization as noticed by many investigators (Akbari *et al.*, 2001).

Hundred seed weight

The result of plant population and NP fertilizer on hundred seed weight is given in Figure 3 and Appendix Table 3. Statistical analysis of the data revealed that plant population and NP fertilizer and the interaction between plant population and NP fertilizer were significant at P <0.05. The maximum hundred seed weight were recorded at combination of (N3P3 xPop2) (21.3g), while the minimum hundred seed weight was recorded at N1P1 x pop4 (18.50g). The increase in seed weight might be due to availability of more resources. The hundred seed weight of the variety was affected by the amounts of nitrogen doses and plant density. The current study aligns with Pedersen, (2008) who found that a seeding rate of 18.5 seeds m^{-2} had a 100-seed wt. of 14.2 g 100 $seeds^{-1}$ and seeding rates of 31.0 to 55.6 seeds m^{-2} had a 100-seed wt. of 14.4 g 100 seeds-1, but these differences were most likely due to different location conditions.

This is current studies align with the studies NPK + Farmyard manure application on soybean had significantly higher 100-seed weight than NPK and control Mandal *et al.*, (2009). This is in line with findings by Tamiru *et al.*, (2012) who reported a significant increase in soybean 1000-seed weight upon inoculation with Brady rhizobium strain.

Biomass yield

The analysis of variance for plant population and NP fertilizer on biomass yield were given in Table 8 and Appendix Table 3. The data revealed that plant population and interaction between plant population and NP fertilizer had significant at p<0.05, while NP fertilizer did not show any signifance difference. Maximum biomass yield was recorderd at the combination of N2P2x Pop4 which (5491.7 kg /ha), while minimum value was obtained at N1P1 Pop1 (3075 kg /ha). This because the biological yield was increased by increasing plant density due to high grain yield, LA, number of grain per pod and plant height in the treatment of high plant population density. These result are in agreement with Bullock *et al.,* (1998) reported that narrow row spacing(low plant population) made 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 decreases progressively as the number of plants increases in a given area because the production of the individual plant is reduced Hamidia *et al.,* (2010).

Grain Yield

Data regarding the effect of plant population and NP fertilizer on grain yield per hectare were given in Figure 4 and Appendix Table 3. Statistical analysis of the data revealed that plant population and NP fertilizer shows significant at p<0.01, while the interaction between plant population and NP fertilizer also show significant difference at p<0.05. The maximum value of grain yield were recoreded at combination of N2P2xPop4 (1960.2 kg/ha, while the minimum grain yield was recorded at N1P1xPop1 (1106.3 kg/ha). The reason for increased grain yield may be due to net crop assimilation rate and more number of plant harvested unit^{-1} areas. The higher grain yield was possibly due to higher LA, plant height, number of seed per pod and biomass yield. These results are supported by Edwards and Purcell, (2005) who showed that as soybean population increases, yield increases rapidly until it becomes asymptotic per plants. Adequate N supply throughout the growing season is 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) state the response to foliar N-P-K fertilizer application varies based on soil test levels and local weather conditions. Nitrogen influenced grain yield through source–sink relationships resulting in higher production of photosynthesis and soybean grain yield was increased by 38.7% when application of N increased from 0 kg N/ha to 90 kg N/ha Asfaw and Angaw, (2003) 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. Nitrogen rate had no effect on seed yield per plant across all N rates. Increasing the population reduced yield per plant but increased yield per unit area Ball *et al.,* (2000).

Harvest index

The main effect of plant population and NP fertilizer on harvest index were given in Table 9 and Appendix Table 3. Plant population and the interaction between plant population and NP fertilizer did not show significant variations on harvest index, while NP fertilizer shows significant at p<0.05. The maximum harvest index of population were recorded at Pop2 (0.42), while minimum harvest index were recorded at Pop1 (0.35). The maximum harvest index of NP fertilizer were recorded at N3P3 (0.40), while minimum harvest index in NP fertilizer were recorded at N1P1 (0.37). This is because harvest index was decreased by increasing plant density due to the increased competition in high densities for resource and it was related with number of branch and leaf area they are maximum in the broader in low population than in high population. These results agree with Malik *et al.*, (2006) who reported N application has effect on harvest index of soybean. These results agree with Board (2000) and Green-Tracewicz (2011) who also found HI non-responsive to plant density, found HI to be stable even after periods of stress throughout plant development.

Correlation Analysis

Correlation analysis between growth parameters, yield and yield related traits, was presented in (Table 10). The simple correlation analysis showed that days to 50% flowering has highly significant at (P <0.01) and positively correlated with number of leaf (r=0.422) and number of branch (r=0.457) and number of pod per plant (r=0.373) and pod length(r=0.504) and highly significant at (P <0.01). This is because it has a positive relationship with those parameters and contribute a great growth performances and yield paramers for the plants. Number of leaf was highly significant (P <0.01) and positively correlated with fresh weight (r=0.477) and leaf area (r=0.403) and with days to 50% maturity(r=0.528) and positively correlated with number of seed (r=0.539) and pod length (r=0.376).means they are the direct relationship on the chlorophyll and photoassmillate for plant growth performance and yield as a well. Number of branch was highly significantly (P <0.01) and positively correlated with number of seed(r=0.404) and pod length (r=0.589). Fresh weight was highly significant (P <0.01) and positively correlated with dry weight (r=0.661) and leaf area (r=0.685) and it also correlate with number of pod(r=0.568) and number of seed (r=0.619). Dry weight was highly significant at (P <0.01) and positively correlated with leaf area (r=0.502), and number of pod (r=0.445). Number of nodules was highly significant (P <0.01) and positively correlated with pod length(r=0.381) and biomass yield (r=0.405). Plant height was highly significant (P <0.01) and positively correlated with leaf area (r=0.558) and biomass yield (r=0.511) and grain yield (r=0.501). Leaf area was highly significant (P <0.01) and positively correlated with number of pod per plant(r=0.436) and number of seed per pod (r=0.529). Days to 50% maturity was highly significant (P <0.01) and positively correlated with number of pod per plant (r=0.412).Number of pod 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 positively correlated with biomass yield (r=0.550). Hundred seed weight was significant (P <0.05) and positively correlated with pod length (r=0.298). Pod length was highly significant (P <0.01) and positively correlated with biomass yield (r=0.386). Biomass yield was highly significant (P <0.01) and positively correlated with grain yield (r=0.922).

The results of the present study showed that main effects of plant population and NP fertilizer as well as their interactions had considerable influence on different growth and yield parameters of soybean in the experimental area. Growing soybean by application of plant population and NP fertilizer could make an important contribution to increase agricultural production and productivity in areas of production where there is low practice of using inorganic fertilizers and plant population. To this end, plant population and NP fertilizer of soybean could be one of the alternatives to improve productivity by small farmers. Thus, this research work was initiated to investigate the impact of plant population and NP fertilizer on the performance of soybean.

The results showed that the main effects of plant population and NP fertilizer as well as their interactions had considerable influence on different growth and yield parameters of soybean; like days to 50% flowering, plant height, number of nodules, number of leaf, leaf area, biomass yield and grain yield. The interaction of plant population and NP ferilizer significantly influenced on number of branches, number of nodules, number of pod 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 pod per plant (67.26) and pod length (8.80) biomas yield(5491.7 kg/ha), and grain yield(1960.2 kg/ha,) were recorded from plant population and 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) biomas yield(3075 kg/ha), and grain yield(1106.3 kg/ha). Were recorded from plant population and NP fertilizer. It was also observed that the main effect of applied plant population and NP fertilizer have effects were found to be significant for days to 50% flowering, days to 50% maturity leaf area, plant height, number of leaf, fresh weiegt, dry weieght, number of seed per pod and harvest index were an effect on the soybean growth and yield on the independent or separate manner.

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 branch, number of nodules hundred seed weight and pod length. In general, plant population and NP fertilizer were effective on improving growth, yield, economic benefits, in soybean plant production and its productivity.

Increased NP fertilizer from the combinatgion of 23/46 kg/ha to 69/69 kg/ha significantly increased days to 50% flowering, days to 50% physiological maturity. Similarly, application of plant population significantly decreased days to 50 % flowering. The combined effect of 69 kg of NP/ha and 400,000 plant/ha increased plant heights, number pod and total biomass, but significantly reduced dry matter content. At the highest NP fertilizer application, highest total grain yield was attained at the recommended fertilizer rate of 23/46kg/ha. Also the highest grain yield was attained from the combination of plant population 166667 with 46/46 and of NP fertilizer. The correlation analysis shows that the relationship between each parameters were highly dependent on one another as one parameter increase the others also increase simoltanously means that as the growth parameters increases the yield performances also increases. Therefore, both the growth and yield parameters are highly and positively correlate 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 46/46kg/ ha NP fertilizer and 166667 plant population per ha, but grain yield per ha due to 23/46 333333 were found significantly comparable.

These results generally suggested that by applying the NP fertilizer at 23/46 for this experiment who produce soybean can grow well and it gave higher yield 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 at 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 is applicable, while plant population of 33333 plant/ha is no longer applicable for enhancing soybean production in Kersa Woreda. Nonetheless, it is too early to arrive at 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, locations, soil types and different fertilizers application and plant population 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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