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Plant Population Density Effects on Yield and yield components of Soybean (*Glycine* max. L.) Varieties in Ethiopia- A Review

BY

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Abstract

Soybean is the most important oil seeds and grain legume crop in the world, in terms of whole manufacturing and international trades. Appropriate plant density is a key for production of soya bean in various environments of Ethiopia. This paper reviews on effect of plant population density on yield and yield components of soybean in Ethiopia. Under these review recent literatures concerning on effect of plant population density has been covered. Optimizing plant population per unit area is one of the best agronomic practices to increase soybean production and productivity. Improvements of inter and intra row spacing practices are important for land productivity to soybean varieties based on the varieties architecture and the environmental yield potential of the land. The yield and yield related parameters of a single plant can be increased by optimum plant population density. As the review indicates most yield components of soybean were affected by different plant population densities due to resource competition that can be affects the grain yield. Normally as population increase yield also increases proportionally. However, after it reached a certain level the yield declines. Population density is also dependant on the moisture availability and nutrient status of the soil. Soybean tolerates considerable variation in plant population density and there is a tendency for higher yields with narrow rows. Several experiments conducted on row and plant spacing under different soil and climatic conditions indicated higher yield and yield components for high planting densities than for low planting densities. The optimum plant population for Soybean could vary depending on geographical locations, morphological characteristics, length of maturity. In Ethiopia, recent studies showed that plant spacing 30-40 cm inter row spacing with 5cm intra row spacing was recommended and economical for early and medium maturing soybean varieties.

Keywords: *Population, density, soybean, spacing, and yield*

1. INTRODUCTION

The soybean (*Glycine max* L.) is the most important oil crop in the world in phrases of complete production and global trades. It is recognized as an oil seed containing several useful nutrients including protein, carbohydrate, vitamins, and minerals. Dry soybean contain 36% protein, 19% oil, 35% carbohydrate (17% of which dietary fiber), 5% minerals, and several other components including vitamins [1]. It is discounted and rich source of protein for poor farmers, who have less access to animal-source protein, because of their low acquiring limit. Soybean is an elective protein source to the rural families and can be utilized at home in different structures and the surplus can be sold to different buyers, producers, and manufacturer for money [2]. In Ethiopia, soybean has been cultivated since 1950s expanding into different agro-ecologies accompanied by increasing domestic demand as food and feed [3]. It can also be used as oil crop, animal feed, poultry meal, for soil fertility improvement, and more importantly as income for the country. In Ethiopia, soybean has adapted to diverse ecological niches and provided wider yield range. Soybean can be grown in different parts of Ethiopia notably in the western and southwestern parts of the country (Benishangul Gumuz, Gambela, and parts of Oromia region). These areas have vast fertile land and a favorable agro-climate suited to growing soybean.

Soybean has wide adaptability coupled with its higher productivity potential as compared to other grain legumes. According to Ethiopian Central Statistic Agency, [4] the production of the soybean was 64,720.12 hectares with 149,454.6 tons of grain yield (2.31 t ha^{-1}) which is low as compared to world average of 2.6 t ha^{-1}; however, this level is very low compared to its potential, which could go up to 4 tons per hectare if improved varieties and agronomic practices are used [5]. At Jimma zone South Western Ethiopia for

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example the average grain yield of 3.7 t ha^{-1} was recorded from plant population density of 400,000 plants ha^{-1} (50cm inter-row x 5cm intra row spacing) during 2015-2017 main cropping seasons [6]. The low yield may be attributed to a combination of several production constraints among which low soil fertility, periodic moisture stress, diseases, insect-pests, and weeds [7]. There might be also low soil N and P content, lack of improved varieties, and poor agronomic practices including zero-inputs of fertilizers and rhizobial inoculants [8]. Soil acidity associated with soil fertility problem is one of the most important soybean production constraints in South Western and Western Ethiopia where most soils with pH levels below 5.5 [9].

Plants show extreme plasticity, responding remarkably in size and form to environmental conditions. One of the most potent of external forces is the presence of competing neighbors, which may reduce a plant to diminutive size. An essential component of plant density is a spatial arrangement [10]. According to Reddy, [11] both too narrow and too wide spacing do affect grain yields through competition and due to the effect of shading. In the case of too wide spacing, yield reduction can occur due to in efficient utilization of the growth factors. Normally, as density increases yield also increases proportionally but after a certain level, it declines [12].

Higher plant densities compared to lower plant density have consistently produced higher seed yields in Northern USA where indeterminate early maturing varieties are used [13]. According to the studies by Sisay *et al*. [6]; Habtamu *et al*. [14]; Caliskan *et al*. [15] the major agronomic practices of which plant population density is the one which is limits the growth and yield per plant but the reverse occurs for yield per unit area. A report by Epler and Staggenborg, [16]; Robinson and Wilcox, [17] indicated that the plant density affected soybean yield and yield components in narrow rows. Under sufficient soil moisture and nutrients, higher plant population density is necessary to utilize all the growth factors efficiently. The level of plant population density should be as such that of which maximum solar radiation was utilized.

Usually, soybean seed yield increases with decreasing row width up to a certain point, after that a further decrease in row width may negatively affect seed yields [18, 19]. Establishment of optimum plant population density per unit area is essential to get maximum yield [20]. Plant spacing is thought of existing in two directions, within row spacing and between row spacing. According Robinson *et al*. [21] arrangement of a population is altered by changing row spacing, planting seeds singly or in groups, or changing row direction. 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 [13]. This review is attempting to overview the effects of plant population density on soybean varieties in Ethiopia.

2. Literature Review

Many experiments have been conducted to determine the spacing between rows and between plants with in the row, which maximizes yield of soybean in Ethiopia.

2.1. Effects of plant population density on yield components of Soybean

2.1.1 Plant height

The maximum plant height of soybean (Clark-63K variety) was recorded from highest plant population density of 400,000 plants ha^{-1} where as the lowest plant height was recorded from lowest plant population density of 166, 667 plants ha^{-1} at Jimma South Western Ethiopia [6]. Also, Worku and Astatkie [22] indicated that soya bean plants grew taller in narrow plant spacing. Yimer *et al*. [23] also indicated that as intra-row spacing becomes wider, plant height decreased significantly and the longest height was measured with the narrowest (5 cm) intra-row spacing, while the shortest plant height was measured with the wider intra-row spacing. Narrow rows (high plant population density) was attributed to maximum seasonal light interception and completion for light was makes the crop to more elongation. The narrowest plant spacing and high plant population density had inter-specific competition among plants for plant development and growth resource. Increased plant height was associated with plant population, but only as final stands were lodging was not a significant problem with greater seeding rates.

2.1.2 Number of branches per plant

An increasing plant population density can decrease both branch and main stem yields per plant [14]. 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. The study by Yimer *et al*. [23] also showed that narrowed inter and intra row spacing (highest plant population density) gave significantly lower number of branches per plant, while wider inter and intra row spacing gave highest number of branches per plant.

2.1.3 Leaf Area

As plant population density increased (up to 400,000 plants ha^{-1}), the leaf area was decreased and vice versa [14]. In soybean one of the benefits of higher plant density is contribution to earlier canopy closure which makes weed control easier by increasing competition between the crop and weeds. When plant populations are low, individual soybean plants increase their leaf area which allows each plant to capture more sunlight and produce more branches which allows each plant to produce more pods. Maximum yield could be obtained only if the plant community produced enough leaf area to provide maximum light interception during reproductive growth.

2.1.4 Number of nodules

As described by Habtamu *et al*. [14], the highest number of nodules was recorded from the highest plant population density (400,000 plants ha^{-1}).whereas the lowest was obtained from the lowest plant population density (166,666 plants ha^{-1}). The Nodule number and dry matter were decreased with increase in plant population density per m^2 [24].

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2.1.5 Number of seeds per pod

As plant population density increased up to 400,000 plants ha^{-1}, seed number per pod decreased [14]. As plant population density increases (i.e. narrow spacing) intensity of interplant competition increases and reduces number of seeds per pod. As report by Yimer *et al*. [23] number of seeds per pod did not show consistent pattern among inter row spacing.

2.1.6 Number of pods per plant

The highest number of pods per m^2 was obtained from 50 cm row spacing, and the lowest was obtained from 70 cm row spacing [22]. Whereas Sisay *et al*. [6]; Sisay *et al*. [25] indicated as plant population density increased up to 400,000 plants ha^{-1} the number of pods per plant decreased by 19.7%. The narrowed intra-row spacing gave fewer pods per plant than wider intra-row spacing [23]. Also, Merga *et al*. [26] reported that the lowest plant population density (wider spacing) of 70 cm inter-row spacing gave highest number of pods per plant. The plant produces branches and more pods per plant if the plant population is low and fewer branches and pods per plant if the plant population is high. This is due to availability of more resources increase in number of pod per plant to plants on account of low population density. As plant population density increases (i.e. narrow spacing) intensity of interplant competition increases and reduces number of pods per plant.

2.2. Effects of plant population density on yield of soybean

2.2.1 above ground biomass

The highest plant population density of 400,000 plants ha^{-1} gave the highest above ground biomass while the lowest above ground biomass recorded from lowest plant population density of 166,667 plants ha^{-1} [6]. These results were indicated there was 30.9% increase of above ground biomass when plant population density increased to 400,000 plants ha^{-1}. Also Habtamu *et al*. [14] was reported above ground biomass, increased as plant population density increased up to 400,000 plants ha^{-1}. The highest biomass per m^2 was obtained from 50 cm row spacing, and the lowest biomass yield per m^2 was obtained from 70 cm row spacing [22]. Also Yimer *et al*. [23] reported that the highest biomass yield were achieved from the narrower inter (40cm) and intra row spacing (5cm), while the smallest biomass were achieved from the wider inter (100cm) and intra row spacing (15cm) at North Western Ethiopia. High plant populations can have advantages of quicker canopy closure, greater light interception, and lower weed competition.

2.2.2 Grain yield

Several experiments conducted on row and plant spacing under different soil and climatic conditions in Ethiopia indicated higher yield and yield components for high planting densities than for low planting densities. If the population is too high, plants compete with each other intern arises from self thinning, lodging, bareness and spindly stacks. If the population is too low, a producer is wasting growing space and lowering yield.

The highest grain yield per m^2 was recorded from the highest plant population density (50 cm row spacing and 2.5 cm plant spacing) [22]. The report by Yimer *et al*. [23] was indicated that the highest grain yield was achieved from narrower inter-row spacing (40cm) and intra row spacing (5cm), while the lower grain was recorded from wider inter-row spacing (100cm) and intra row spacing (15cm) at Pawe North Western Ethiopia. Also, other experiment done at Pawe indicated that the highest grain yield per hectare was recorded from 40cm inter-row spacing [26]. Habtamu *et al*. [14]; Sisay *et al*. [6]; Sisay *et al*. [25] reported that the highest plant population density (400,000 plants ha^{-1}) gave the highest grain yield while the lowest plant population density (166,666 plants ha^{-1}) gave the lowest grain yield. As plant population density increased grain yield dramatically increased by 31.8% and soybean grain yield was responded more to plant population density than NP fertilizer rates [6]. The reason for increased grain yield may be due to more number of plants harvested per unit areas rather than increased yield per plant. The recommended plant spacing for early and late maturing varieties is 40 x 5 cm and 60 x 5 cm respectively as indicated by Ministry of Agriculture (MoA), [27]. The highest grain yields were recorded at 40cm inter and 5 cm intra row spacing at North Western Ethiopia as reported by Yimer *et al*. [23].

3. SUMMARY AND CONCLUSIONS

Growing soybean by good management practices with best plant population density can make an important contribution to increase production and productivity. Among the good management agronomic practices management is crucial for the best yield and productivity of the crop. Based on the review, soy bean yield, yield related parameters and resources utilization are highly depending on plant population density. Soybean plants in low populations will produce more branches, more pods and more seeds per plant. Soybean at higher populations will grow taller, produce fewer branches, pods and seeds per plant. However, yield does not always increase as plant population increases. Under most circumstances, soybean yield increases with plant population density until a point at which yield either plateaus or decreases. This is due to competition effect of the plant such as light, nutrients and water, the rate and extent of vegetative growth and development of crops.

Hence, as a future line of works that consider crop growing season, ecology, soil types and different fertilizers application, crop protection and management of agronomic practices are needed for increased production and productivity of soybean. At low plant population density, seed yield is limited by the number of plants, whereas at higher plant population density it declines due to increase in barren stalks and stalk lodging. Optimum plant population density will lead to effective utilization of soil moisture, nutrients, sunlight etc and establishment of required plant density is essential to get maximum grain yield of soybean. So, it is relevant to identify the appropriate plant population in each area where soybean is cultivated. Seed yield per unit area is the product of number of plants per unit area and seed yield per plant. In Ethiopia, recent studies showed that plant spacing 30-40cm inter row

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spacing with 5cm intra row spacing was recommended and economical for early and medium maturing soybean varieties. To solve the problem of yield reduction of soybean in the country efforts should be made to promote farmers on use of optimum plant population density (plant spacing) and increasing yield per unit area and efficient use of resource (water, light, nutrient and even the land). In addition to these establishing guide lines under farmer level on plant population density (plant spacing) and continuous follow up of farmers' production to obtain best yield in all locations of Ethiopia.

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