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Review on Effects of Inter and Intra Row Spacing on Yield and Yield Components of Soybean (Glycine max (L.) Merrill) in Ethiopia

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Abstract
Plant density and arrangement of plants in a unit area greatly determine (i) resource utilization such as light, nutrients and water, (ii) the rate and extent of vegetative growth and development of crops particularly that of leaf area index, plant height, root length and density, (iii) yield components and yield, (iv) development of important diseases and pests, and (v) the seed cost. Plant density affects early ground cover, competitive ability of crops with weed, soil surface evaporation, light interception, lodging and development of an optimum number of fruiting sites in a crop canopy. It also affects canopy development, plant architecture and distribution of pods. Use of proper agronomic practices is one of the important factors which contribute for the increase of yield per unit area. Plant density is one of the essential agronomic practices as it is a major management variable used in matching crop requirements to the environmental offer of resources. Plant density is determined either by seed rate (for broadcast planting) or by inter- and intra- row spacing (for row planting). The density depends on the germination percentage and the survival rate in the field. Establishment of required plant density is essential to get maximum yield. For example when a crop is raised on stored soil moisture under rain fed conditions high density will deplete moisture before crop maturity, whereas low density will leave moisture unutilized. Hence, optimum density will lead to effective utilization of soil moisture, nutrients, sunlight etc. In Ethiopia, studies showed that plant spacing recommended for early and late maturing varieties was 40 cm x 10 cm and 60 cm x 5 cm, respectively. However, use of below (30cm x5cm spacing for all varieties, indiscriminately) and above the recommended spacing have effect on the yields of soybean in Ethiopia.
Keywords: Intra row spacing, Inter row spacing and plant density

1. Introduction

Soybean (*Glycine max* (Linn.) Merr.) is the world's most important grain legume in terms of production, consumption and economic importance (Baten, *et. al.,* 1992). It has an average yield of 0.35t/ha in Nigeria. This is by far lower than the world's average of 1.7t/ha and an African average of 1.1t/ha (Food and Agricultural Organisation, 1989). Therefore, in Nigeria there is the need to increase soybean production and monitor the yield. Research findings on various species of grain legumes have indicated that photoperiod and temperature responses, photosynthetic source limitations disease and insect resistance, the efficiency and effectiveness of nitrogen fixation, farmer's experience, soil characteristics and competition, have significant effects on their performance and grain yield (Imrie and Butler, 1983; Baten, *et. al.,* 1992).

Because of constraints like disease, Pests, soil and agronomic factors, the average yield of soybean in Ethiopia ranges from 1000-2900kg/ha (ARC, 2004). Soybean has spread to different countries in the world and became an established component of world agriculture. Among grain legumes, soybean has the highest protein and oil content. The soybean seed on an average contains 40% protein and 20% oil, 35% carbohydrate and about 5% ash, which determine the economic worth of seed in the globe (Normal *et al*., 1995; Thomas and Erostus, 2008). Its protein has a good balance of the essential amino acid approximating the standards established by FAO (FAO, 1994).

Currently in Ethiopia, soybean covers about 7807 ha land and 8400.64 tones of soybean is produced per annum with average productivity of 1.076 t/ha (CSA, 2008). It is a crop of growing importance in the country as it has demonstrated an increase in area from 1027 ha in 2004 to 7807 ha in 2008 under private peasant holdings (CSA, 2004, 2008). The soybean research team of Ethiopia has recently released two varieties namely Awassa-95 (G-2261) and Belessa- 95 (IP-149). The former is early to medium and the later is late type in its maturity duration (ARC, 2004). The recommended plant spacing's for early and late varieties were 40x5cm and 60x5cm respectively (IAR, 1983).

Environmental condition during the growing season, especially intensity and quality of solar radiation intercepted by the canopy are important determinant of yield components and photosynthesis variation in environmental resources may bring about alternation in growth patterns of crop. Therefore, there is a differential response of yield components to change in the environmental conditions for example the shading effects are more pronounced by cultural practices of intercropping and population density (Putnam *et al.,* 1986). One of the major problems with the farmers is non adoption of the recommended spacing (60 cm x 5 cm) in soybean; instead they prefer wider spacing with reduced seed rate in the study area. Therefore, to solve this problem these reviews had been conducted to identify effect of inter and intra row spacing on growth, yield attributes and yield of soybean in Ethiopia.

2. Taxonomy

The soybean (American phonetic) or soyabean (United Kingdom phonetic) is a species of legume native to East Asia. The English word "Soy" is derived from the Japanese pronunciation of shoyu, the Japanese word for soya sauce. "Soya" comes from the Dutch adaptation of the same word. The plant is sometimes referred to as "greater bean" (By the Chinese), 'daunanh" (by the vietnamese), and "edamame" (by the Japanese) (Chinese Report, 2010; SARE, 2004). The genus name, *Glycine*, was originally introduced by Carl Linnaeus (1737) in his first edition of 'Genera Plantanum'. The w ord "*Glycine*" is derived from the Greek, "glykys" which means "sweet", and likely refers to the sweetness of the pear – shaped (apios in Greek) edible tubers produced by the native North American Twining or climbing herbaceous legume, *Glycine apios*, now known as *Apios americana*. The cultivated soybean first appeared in 'Species Plantanum' by Linnaeus, under the name *Phaseolus max* (Linn.) the combination *Glycine max* (Linn.) Merr., as proposed by Merrill in 1917, has become the valid name for this useful plant. The genus Glycine is divided into the sub genera *Glycine* and *Soja*. The sub genus *Soja* (Moench) Herm. includes the cultivated soybean, *Glycine max* (Linn.) Merr. and the wild soybean, *Glycine soja* (S) Zucc. Both species are annual. *Glycine soja* is the wild ancestor of *Glycine max* and grows wild in China, Japan, Korea, Taiwan and Russia. The subgenus, *Glycine* consist of at least 16 wild perennial species (Singh *et al*., 2006).

2.1 Origin and Distribution

Soybean is native to East Asia but only 45% of soybean production is located there. The other 55% of production is in the Americas. The United States produced 75million tons of soybeans in 2000, of which more than one – third were exported. Other leading producers are Brazil, Argentina, Paraguay, China and India. *G. canescens* (Herm.) and *G. tomentella* (Hayata) were reported to be found in Australia and Papua New Guinea (Hymowitz, 1995; Newell and Hymowitz, 1983).Soybean was domesticated in the 11th century BC around northeast of China. It is believed that it might have been introduced to Africa in the 19th century by Chinese traders along the east coast of Africa – cultivated in Tanzania in 1907 and Malawi in 1909 International Institute of Tropical Agriculture, 2009). Increase in soybean production in Brazil has been said to cause a thorough damage on the Amazon rain forest and encouraging deforestation (Fargione, 2008).

2.2 Description/Habit

Soybean is an annual herbaceous plant that has been used in China for about 5,000 years to primarily add nitrogen to the soil as part of crop rotation. The root system is diffuse or it is weakly tap – rooted. The plant varies in height from 20cm to more than 2m at maturity (Langer and Hill, 1991) and in habit from stiffly erect to prostrate. It may be sparsely or densely branched depending on cultivars and growing conditions (Carlson, 1973). The leaves are green in colour, compound, usually trifoliolate and alternate. Each leaflet has an approximate length of 6-15cm and 2 – 7cm wide. The leaves fall before the seeds are mature. Flowers are often borne at the nodes and in short axilliary or terminal racemes. The entire shoot system is pubescent. The pods, stems, and leaves are covered with fine brown or grey hairs. Pods (usually light brown in colour) in most varieties are covered with numerous, fine, white or tan coloured hairs. Pods grow in clusters of three to five with each pod usually containing two to four (rarely more) seeds. Each pod is 3-8cm long (1-3 inches) and 5 – 11mm in diameter. Seeds are quite small compared with most other grain legumes, 1000 seeds may weigh between 50 – 400g (Langer and Hill, 1991).

Soybean occur in various sizes, and in many hull or seed coat colours including black, brown, yellow, green, etc. The hull of the mature bean is hard, water resistant, and protects the cotyledon and hypocotyl (or "germ") from damage. If the seed coat is cracked, the seed will not germinate. The scar, visible on the seed coat is called the hilum and at one end of the hilum is the micropyle, or small opening in the seed coat which can allow the absorption of water for sprouting. Remarkably, seeds such as soybean containing very high levels of protein can undergo desiccation yet survive and revive after water absorption. They can be planted in rows 20 – 40cm apart and in some cases as wide as 75cm and 7-10cm between plants within a row at a depth of 2-5cm. 1-3 times weeding is recommended during the first 6-8 weeks after planting to increase yield (IITA, 2009).

3. Environmental Factors Influencing Growth and Development of Soybean

3.1 Growth and development

Soybean varieties differ in agronomic traits including days to R2(Flower initiation) and R7(Physiological maturity), plant high at R2(Flower imitation) and R7 (Physiological Maturity), flower color, branches/plant, leaf color, pubescence color if present, pod and stem color, pod length, seed color, 100 seed weight and shape (FAO, 1982). Days to R7 (Physiological maturity) and plant height increased with increasing altitude and latitude and yield is increased with increasing plant height and days to R7 (Physiological Maturity), but it depend with increasing altitude and latitude (Kratochvil *et al*., 2004). Several researchers reported that agronomic performances of soybean varieties differ greatly in response to seeding rate and planting pattern (Nangju, 1979; Muleba and Tom, 1983). In other review, it was concluded that yield response to plant populations and rows width occurred in environments where vegetative growth was restricted by some forms of stress Kratochvil *et al*., 2004). Otherwise, row spacing's had no positive or negative effect on soybean yield (Devlin *et al*., 1995; Kratochvil *et al*., 2004). Soybean was first introduced to Ethiopia in 1950`s because of its nutritional value, multipurpose use and wider adaptability in different cropping systems (Amare, 1987 and Daniel, 1996). However, this attempt was unsuccessful primarily due to un acceptability by the farmers, which was due to lack of knowledge of domestic consumption and market constraints. The next introductions were made by CADU in collaboration with the ENI (Ethiopian National Institute) in 1970`s namely to replace imports of soybean used in children meal and introduce soybean in to the local diet of the community (Singh *et al*., 1987; CGIAR, 2004).

Based on the adoption trial at Arsinegelle, Awassa, Debirezeit, Abella, Anger Gutin, Dedessa, Nazareth, Pawe and Jimma, the crop grows very well from 300 to 2200m above sea level,where average mean annual temperature range between 20-25^{0}C and pH varies from 5.5 to 7 (ARC, 2004). Studies also showed that the yield range from these areas was between 1000 to 2900kg/ha depending on the management (ARC, 2004). Plant spacing recommended for early and late maturing variety was 40cmx5cm and 60cmx5cm respectively (IAR, 1983). Intercropping Soybean with maze showed advantages of 36% at Jimma. Strip cropping of 6, 12, 18 rows of maize with 7 rows of soybean were recommended for the growers. Planting date trials indicated that sowing from Jun 9 to July 30 could be used in Bako and Awassa areas (Girma,Tilahun and Tesfa, 1996).

Soybean requires a temperature of 25^{0}c- 30^0 c for optimum growth, nodulation and nitrogen fixation. The optimal root zone temperature below 25^0 C adversely affects growth, development, dry matter production and grain yield (Summerfield and Wein, 1982). Furthermore; low root zone temperatures affect nodule development and nitrogen fixation. Thus, temperature is one of the major limiting factors in soybean production in areas with relatively short growing seasons. The environment to which plants respond results from the interaction among atmospheric and soil factors as well as physiological and morphological characteristics of the plant. Water use by soybeans varies with climatic conditions, management practices and length of the growing season. Moisture availability is particularly critical during two periods of soybean development; these are the crop emergence and pod filling. When soil moisture, soil temperature and planting depth are optimum, soybean seedlings emerge 4 to 5 days after seeds are planted (FAO, 1982). Prompt emergence of soybean seedlings in the field is important for weed control. Soil temperature has influence on germination and emergence of soybean seeds.

Rapid germination and emergence was observed at 30^{0}c, where as the reverse was true when the soil temperature was as low as 10^{0}C (Little johns and Tanner, 1976). High day and night temperature at early flowering and pod setting was reported to affect seed growth rate and reduce final seed size attributing to low grain yield (Egli and Wardlw, 1980). Cooler soils often require 10 to 14 days to emerge but later plantings, when the soil is warm the crop emerges in 5 to 7 days (Kipps, 1970). There was a significant relationship between seed yield and amount of rain fall during the period between flowering and pod formation. The plant activity accumulates nutrients from the soil during most of the pod and seed formation period. Moisture stress during pod filling stage reduces yield more than the stress during earlier stages of growth including the flowering stage (IAR 1985).

3.2 Shading and temperature effects on nodulation and symbiotic nitrogen fixation

Light is one of the most significant factors affecting seed yield in soybean. Kakiuchi and Tohru, (2000) reported that shading treatment decreased the pod and seed number per plant. Light intensity was reported to affect growth, nodulation and symbiotic N fixation in legumes. Symbiotic N fixation in leguminous plant depends on the inherent characteristics of the host plant and on the associated *Rhizobium* strain. Nodulation and N fixation by many legumes are more sensitive to root temperature than plant growth (Trang and Giddens, 1980). Nodule number and total dry weight of nodules per plant on plant treated with 30 ppm N were lower than those with no applied N. Several workers (Pal and Saxena, 1975; Trang and Gidden 1980; Pal and Sexena, 1983 Pal and Norman, 1987; Olufajo *et al*., 1988) have reported reduction in nodulation and symbiotically fixed nitrogen resulting from applied nitrogen. Nodules of soybean develop from cortical cells that were nodule primordial, which is observed after six days of planting but nitrogen fixation was detected two to three weeks later. Infarct, nodulation in soybean starts when the plants are 5-6 leaves stage and continues until the first indication of leaf yellowing during late pod-filling stage. However, maximum nodulation and rate of nitrogen fixation was reported to occur after R2 (Pal and Sexena, 1975b; Shibles *et al.,* 1978; FAO, 1982). Soybean can fix between 14-300kg N/ha, depending on its yield potential, availability of soil N, and genetic instruction between the host genotype and the *Bradyrhizobium japonicum (*Pal and Saxena*,* 1975b, Singltin *et al*., 1986; Marschnuer, 1995).

Relative growth rate of soybean tops was significant higher at 30°c root temperatures than at lower temperatures (Trang and Giddens, 1980). Furthermore, optimum dry matter production has been reported to be associated with temperature between 25°c and 28°c although the plants grow at near optimum rates even at 32°c (Trag and Giddens, 1980). As (Trag and Giddens, 1980).reported that there was a significant increase in percent and total N of soybean tops at 25°C and 30°C whereas N content in plant roots was lower at higher root temperatures. Nitrogen fixation in legumes depends up on an ample carbohydrate supply. The nodulation of soybean is limited to sites between the root tip and the smallest emerging root hairs, and does not occur on the walls of mature roots (Puppk, 1983).

Low population of *Bradyrhizobium japonicum* and its mobility in clay soils have a negative effect on nodulation. Mobility of the symbiotic inoculation on to the seed is very poor in clay soils. The movement of bacterium in the soil depends on the percolation of water, which, intern, the lower mobility of the micro-symbiotic (Yong and Dunigai 1985).

3.3 Effect of inter and intra row spacing on yield components of Soybean

The environmental stress affecting final yield occurred during the development of bean plants, the yields that is formed first in the reproductive phases, pods / plant, generally showed the greatest stress response, followed by seed per pod and weight per seed (Buttery, 1969).

The spatial distribution of plants in a crop community is an important determinant of yields. Many experiments have been conducted to determine the spacing between rows and between plants with in the row, which maximizes yield. There are two general concepts frequently used to explain the relationship between row spacing, plant density, and yield. First, maximum yield could be obtained only if the plant community produced enough leaf area to provide maximum light interception during reproductive growth (Shibles and Weber, 1966). Secondly, equidistance spacing between plants affected inter plant competition. Hence it will be imperative to adjust the spatial distribution of the recommended population in order to have maximum yield (Buttery, 1969).

As Holshouser and Joshua (2002) concluded that soybean varieties did not respond to row spacing (23 or 46cm) irrespective of maturity duration of varieties, population density and location with varying degrees of drought stress. The advantage obtained in narrow rows was attributed to maximum seasonal light interception and early season suppression suppression (Johnson, 1987, Olufajo and Pal, 1991).

According to Norman (1963), it is clear that both too narrow and too wide spacing do affect grain yield through competition (for nutrients, moisture, air, radiation, etc) and due to the effect of shading. In the later case (too wide spacing), yield reduction can occur due to inefficient utilization of the growth factors. 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. Hence, optimum planting density should be determined through conducting experiments (Norman 1963).

In narrow rows control of weeds was unsatisfactory, uniform stands were difficult, susceptibility to logging was frequent and inability to reproduce results in different locations within a country was reported and yield response was inconsistent (Olufajo and Pal, 1991). The rule of thumb is that row width should be narrow enough to provide closed canopy by the time of R2 (Herbek and Bitazer, 2004). Shibles *et al.* (1978) reported that all nodes of soybean plant have a potential both for branching and floral development, but the number of branches may vary from 0-6 depending on the population density. Hence it may be concluded that soybean tolerates considerable variation in plant population and narrow width without significant change in seed yield, but there is a tendency for higher yields with narrow rows.

Smith and Hamel (1999) indicated that branching and/or tillering are important characteristics by which plants may adapt their size to the availability of resources. According to them, soybean and wheat showed close to maximum yield at the lowest plant populations and little or no yield decline as compared to greater plant populations because of their branching and tillering nature. Where as, single stemmed maize plants are unable to fully exploit the resource available at low plant populations and show stunted yield reduction with respect to the maximum range Smith and Hamel (1999). In soybean; indeterminate types were taller which is generally equated with more vegetative growth, but corresponding yield advantage was not evident. The population and growth habit interaction affected seed yield in soybean. However, growth habit difference was consistent across population for days to maturity and number of main stem pods (Beaver and Johnson, 1981).

3.4 Inter and intra specific competition

The spacing between stands is largely determined by the extent of the root and the shoot systems of the crop plant in question. The spacing between stands per hectare intern determines the number of stands per unit area (Onwueme and Sinha, 1991). A number of factors also influence spacing: including fertility status of the soil, growth pattern of the crop and cultural practices. Light is one of the most significant factors affecting seed yield in soybean as compared with temperature, soil fertility and soil water conditions. Assimilate supply and the sink capacity of harvest organs are main factors influencing yield components of soybean. The yield is closely related to the penetration of light in to the canopy on the arrangement or density of the plants and the revival of interest in narrow spacing (Martin *et a*l., 2006).

Kakiuchi and Tohru (2000) reported that reduced plant density by thinning treatment in the standard and low plant density increased the total pod, filled pod, and individual seed weight. The average number of nodes per plant for normal density was low and no effect on seed size was observed by Buttery (1969). Kakiuchi and Tohru (2000) indicated that shading treatment decreased the pod and seed number per plant. These decreases were correlated with level of shade, but number per pod and individual seed weight were not affected. As a result, seed weight per plant in standard plant density and low plant density treatment increased with reduction in plant density by thinning and decreased according to the strength of shade. In the standard plant density and low plant density treatments, filled pod number increased with increase in total pod number. According to Donald (1963) both inter and intra plant competition for light occurred which suggested that both defoliation and stand reduction affect photosynthetic rate and dry matter production.

4. Conclusion

Generally crop production in Ethiopia is a chain of interrelated economic activities under taken with local farmers. A vast number of farmers actively participate in crop production using their own local knowledge of field management to generate food and income requirement of the households. Plant density affects early ground cover, competitive ability of crops with weed, soil surface evaporation, light interception, lodging and development of an optimum number of fruiting sites in a crop canopy. It also affects canopy development, plant architecture and distribution of pods. Use of proper agronomic practices is one of the important factors which contribute for the increase of yield per unit area. Among that practice arrangement of plant in row or plant density in the given farm is one of the essential agronomic practices as it is a major management variable used in matching crop requirements to the environmental offer of resources. Plant density is determined either by seed rate (for broadcast planting) or by inter- and intra- row spacing (for row planting). The density depends on the germination percentage and the survival rate in the field. Establishment of required plant density is essential to get maximum yield. For example when a crop is raised on stored soil moisture under rain fed conditions high density will deplete moisture before crop maturity, whereas low density will leave moisture unutilized. Hence, optimum density will lead to effective utilization of soil moisture, nutrients, sunlight etc. In Ethiopia, studies showed that plant spacing recommended for early and late maturing varieties was 40 cm x 10 cm and 60 cm x 5 cm, respectively. However, use of below (30cmx5cm spacing for all varieties, indiscriminately) and above the recommended spacing have effect on the yields of soybean in Ethiopia.

Plant spacing have effect on the crop growth, yield components and yield of soybean due to competition effect of the plant such as light, nutrients and water, the rate and extent of vegetative growth and development of crops particularly that of leaf area index, plant height, root length and density, yield components and yield the major problems in the country. With the rise of density, the dry matter produced in both sole cropping (monocultures) and intercropping increased. High plant density particularly as to forage crops, creates a suitable microclimate and results in the rise of total dry matter yield. To solve the problem of yield reduction efforts should be made to promote farmers on use of best plant spacing that can not affect the overall plant population that cause yield reduction. In addition to these establishing guide lines under farmer level on plant spacing and continuous follow up of farmers' production to obtain best yield in all location.

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