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EFFECTS OF INTRA-SPECIFIC COMPETITION ON SEEDLING GROWTH IN SOYBEANS (*GLYCINE MAX* (LINN.) MERR.)

BY

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DEDICATION

I dedicate this research work to the Almighty God for giving me the grace and enablement to complete my studies in the University successfully.

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ABSTRACT

The effects of intraspecific competition on the growth of *Glycine max* seedlings grown in horticultural pots were investigated. The pots were filled to near brim with top soil collected from the fallow land behind the School of Sciences building, Federal University of Technology, Akure (FUTA). Three seedling regimes otherwise called treatments namely four, six, and eight densities were investigated with control. Seedlings were given three weeks to establish and analyses carried out weekly for five weeks. Growth indices analysed include; shoot height, root length, number of leaves, leaf area and total plant biomass. The result shows that intraspecific competition has no significant effect ($P>0.05$) on shoot height, but in terms of root length, number of leaves and leaf area, there is significant difference ($P<0.05$) as from the fifth week after planting. In terms of total plant biomass, it is significant ($P<0.05$) as from the third week after planting under the densities studied. It appears that the effect of intraspecific competition is more pronounced on the leaf area and biomass. This knowledge can help to increase the growth and yield of soybeans and to manage weeds effectively.

CHAPTER ONE

INTRODUCTION

Competition exists between plants where independent demands for environmental factors exceeds supply and this can be intraspecific or interspecific. Interspecific competition is a competitive interaction that exists between organisms of different species while intraspecific competition occurs between organisms of the same species. Interspecific competition appears to be more common, although, the effect of intraspecific competition within a plant population has been reported to cause a decrease in growth and yield of monocultures (Schwinning and Weiner, 1998).

Competition focuses on the reduction in fitness brought about by a shared requirement for a resource in limited supply (Silvertown and Charlesworth, 2001). Quantifying the size structure of a population is clearly an important pre-requisite for determining the role of plant competition (Weiner and Solbrig, 1984). Competition plays a major role in generating the plant-to-plant variability in relative growth rates that affect frequency distributions of weight (Weiner and Thomas, 1986). The symmetry of competition also affects the development of frequency distributions. Asymmetrical competition occurs when a small number of large individuals utilize a disproportionately large share of the available resources to the detriment of the growth of smaller neighbours. In symmetrical competition, the growth of each individual plant is in equal proportion. In general, asymmetrical competition leads to greater inequality of biomass within a population. There are, however, complex interactions between the spatial arrangement of plants, the nature of the resources, the spatial heterogeneity of the resource, the episodic availability of the resource and the plant's physiological and morphological response to levels of resource supply (Schwinning and Weiner, 1998). These complex interactions increase the possibility of asymmetrical competition to occur. The development of a size hierarchy has described by numerous population models (Westoby, 1982; Firbank and Watkinson, 1985a; Benjamin, 1988; Pacala and Weiner, 1991), and many factors, such as the number of neighbours and relative emergence time, have been considered as important in determining the position of an individual with a size hierarchy (Benjamin and Hardwick, 1986; Wyszomirski *et. al.,* 1999).

The major environmental factors in intraspecific competition are light, space, water, and mineral nutrients. Light is a major determinant of dry matter production and competition for light has been shown to be of major importance in competitive interactions. When other environmental and soil factors are not limiting, light therefore, becomes the factor determining productivity of crops

(Marshal and Willey, 1983), although, it is the combining effect of all the factors that leads to the reduction of biomass as a result of competition.

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).

Of all the forty species of genus, *Glycine*, only one, *Glycine max* (Linn.)Merrill is widely cultivated (Ustimenko-Bakumovsky, 1983). *G. max* is a unique crop, containing 40-45% protein, 17-26% fat and 20-30% extracted substances. The principal product from *G max*, therefore, is oil for consumption and industrial purposes and the protein meal. The importance of *G max*. In nutrition lies in its high amount of essential amino acids which are necessary for human and animal growth than many other vegetable proteins (Williamson, 1976) as more than 90% is ingested. Whole soybean seed can be processed into human food in a variety of ways. Presently in Nigeria, such food include; 'akara', 'moi-moi', 'soy-ogi', 'soy-milk', 'da dawa' and 'artificial meat'. Due to its nitrogen-fixing ability, the crop helps in maintaining soil fertility. It is equally a desirable hay, fodder and green manure crop (Ahuama, 1996). It is therefore, important to monitor the growth and yield of this all-important crop, as even intraspecific competition can limit its productive potential.

The aim of this project therefore, is to study the effects of intraspecific competition on the growth of soybean seedlings.

CHAPTER TWO

LITERATURE REVIEW

2.1 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 word "*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 subgenera *Glycine* and *Soja*. The subgenus *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). The scientic classification of *G. max* is presented below.

Scientific clarification

Kingdom: Plantae

Phylum: Magnoliophyta

Class: Magnoliopsida

Order: Fabales

Family: Fabaceae (Papilionaceae is preferred by some Authors)

Subfamily: Faboideae

Genus: *Glycine*

Species: *G. max*

Authority: Carl Linnaeus (1737)

Merrill (1917)

2.2 Origin and Distribution

Glycine max (L) Merrill (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)

2.3 Description/Habit

Glycine max 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).

G. max 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 *G. max* 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).

2.4 Growth and Development

Growth, development and yield of soybeans are as a result of a variety's genetic potential interacting with the environment and farming practices. Correct production decisions using plant growth staging and timing are important for successful soybean production. Minimizing environmental stress will optimize seed yield. Management practices that may influence crop growth include; seed bed preparation, variety selection, planting rate, planting depth, row width, pest management (diseases, insects and weeds), fertilization and harvesting. Short day length and warm temperatures control soybean flowering. Soybeans must reach at least the first trifoliolate in growth before they can be induced to flower. The reproductive stages in soybean are divided into four parts – flowering, pod development, seed development and plant maturation (Wax and Pendleton, 1968).

Soybean seed begins germination when the water absorbed is equal to about 50% of the seed's weight. Emergence normally takes five to ten days depending on temperature, moisture conditions, variety and planting depth. During this time, lateral roots are also beginning to grow from the primary root. Root hairs can be visible within five days of planting and provide the key nutrient and water absorbing functions of the plant in this early stage. Eventually, the soybean root will reach a depth of 1.6 to 2.6m with most of the roots at the superficial layer of the soil. Soybeans should be planted one-to-one inch deep but not deeper than 2 inches, because the strength needed by the hypocotyls to push the cotyledon above the soil surface, deeper planting can limit viability of seeds

and final stand number. Soybean is very sensitive to salt. After germination (epigeal, i.e, cotyledons are pushed out of the soil). Unifoliate leaves emerge and are fully expanded. During this period, cotyledon supply the nutrient needs of the young plants (for about 7-10days). The cotyledons will lose about 70% of their dry weight to this nutrient reallocation. If one cotyledon is lost during this time, there is little effect on the plant's growth rate. However, loss of both cotyledons at or soon after emergence will reduce yield by 8-9%. When the first trifoliolate emerges, photosynthesis in the developing leaves allows the plant to sustain itself. Every 3-5 days, the trifoliolates continue to change until they reach maturity. The reporoductive stages involved are; emergence of first flowers, flowers of pod, flower's in full bloom (i.e, top two nodes), development of pod, pod maturity, seed development, full size seed develops, one fully matured pod, 95% of the pods on the plant then matured. Soybeans attain maturity during the early part of year (january. to march) (McWilliams *et al.*, 1999)

Either directly or indirectly, most plant problems are caused by environmental stress. In some cases, poor environmental conditions (e.g, too little water) damage a plant directly. In other cases, environmental stress weakens a plant and makes it more susceptible to disease or insect attack. Evnironmental factors that affect plant growth include; light, water, humidity and nutrition. It is important to understand how these factors affect plant growth and development. With a basic understanding of these factors, you may be manipulate plants to meet your needs, whether for increased leaf, flower, or fruit production. By recognizing the roles of these factors, you also will be better able to diagnose plant problems caused by environmental stress (Fehr and Caviness, 1977)

The three environmental stresses which affect the growth and development of soybeans are light, water and temperature. At cool temperatures and during excessive rainfall, the initial growth may be reduced or maturity delayed. Also, soybean is a photoperiodic crop, therefore, responds to day length so the actual planting date is highly latitude and location (Grimm, *et. al.*, 1993)

2.5 Reproductive Potential

Cultivation is successful in climates with hot summers, with optimum growing conditions in mean temperatures of 20 to 30^{o}C; temperatures below 20^{o}c and over 40^{o}c retard growth significantly. They require 500 – 850mm water during the growing season. They can grow in a wide range of soils, with optimum growth in moist alluvial soils with a good organic content. Soybeans, like most legumes, perform Nitrogen – fixation by establishing a symbiotic relationship with the

bacterium, *Bradyrhizobium japonicum* syn. *Rhizobium japonicum* (Jordan, 1982). However, for best results an inoculum of the correct strain of bacteria should be mixed with the soybean seed before planting. Modern crop cultivars generally reach a height of around 1m and take 80 – 120 days from sowing to harvesting. Self fertilization practiced by soybean also boosts its reproductive ability.

2.6 Agronomy

Soybean maturities will vary from one year to the next depending on growing conditions. Some soybeans are more heat sensitive than others, therefore, during an extremely hot year these soybeans mature earlier than normal. All soybeans are photo-period sensitive and will mature according to night length. This is why a one week delay in planting results in only a 1 to 2 day delay in maturity (Burnside and Colville, 1964).

The height a soybean plant achieves is dependent on several factors including planting date, row width, maturity of the soybean for the area, growing conditions and genetic ability.

From a weed management standpoint, perharps the greatest influence that narrow row spacing have in soybeans is in the reduction in the amount of light that reaches the soil surface and in the reduction in the amount of time that it takes for soybean to reach full canopy closure. Puricelli *et al.*, 2003 and, Steckel and Sprague, 2004, have both detected significantly less radiation at the soil surface in narrow-row compared to wide-row soybean throughout most of the growing season. Results from other studies have also revealed that narrow-row soybeans reach complete canopy closure quicker than wide-row soybeans (Shibles and Weber, 1965). Reductions in light penetration and time for canopy closure have a profound influence on the likelihood of weed emergence later in the growing season, a phenomenon which Yelverton and Coble (1991) first termed, 'weed resurgence'. They reported that as row spacing increased, weed resurgence also increased. Weed control was more effective in the narrow-row compared to wide-row soybean, which was attributed to quicker canopy closure and reduction in light penetration (Mickelson and Renner, 1997). In addition to effects on weed resurgence, row spacing has a profound impact on the critical period of weed control in soybean. The critical period of weed control is an interval of time in the growth of a crop during which it is essential to control weeds in order to prevent unacceptable yield losses (Knezevic *et. al.*, 2002). The beginning of the critical period of weed control is determined by the critical time of weed removal, which is time at which weeds must be removed because the crop can

no longer withstand early season weed competition and will begin to suffer irrevocable yield losses. Mulugeta and Boerboom (2000) found that the critical time of weed removal occurred much earlier in wide-row compared to narrow-row soybeans. For soybean producers, results from these studies reveal that planting soybean in wide-rows will require implementation of weed removal practices much earlier than in narrow-rows

2.7 Pests and Diseases

Disesases often go unnoticed in soybean fields, although, it may be causing significant yield losses. Most major soybean diseases are associated with cool, wet conditions and heavier soils. The most cost effective means of controlling disease is through genetic resistance. The shattering of pods in hot dry savanna environment reducing seed longevity is a major constraint in the tropics. Including diseases such as; Asian soybean rust, red leaf, blotch, frog – eye leaf spot, brown stem rot, soybean cyst nematode, sudden death syndrome, stem canker, iron deficiency chlorosis, *Sclerotina* white mould, *Phytophthora* root rot, bacteria pustule and bacterial blight. Asian soybean rust particularly is the most destructive foliar disease of soybean in recent times and can cause 50 – 60% yield loss. It is a major disease worldwide, first reported in 1998 in Uganda and Zimbabwe; and in 1999, its existence was reported in Nigeria, Cameroon and Benin Republic. In Nigeria, the disease kept on recurring every season since 1999. Among insect pests, pod sucking and defoliating insects (most especially, Aphids, Grasshoppers and Locusts) are major constraints and they include; bean leaf beetle, blister beetles, grape colaspis (and its larva), Japanese beetle, Mexican bean beetle (and its larva), armyworms, corn ear worm, green clover worm, soybean looper, velvet bean caterpillar, stink bugs, soybean stem borer and three cornered alfalfa hopper. As a result of pests and diseases, the average grain yield of soybean in Tropical Africa is low (less than 1 ton/ha) (IITA, 2009; Langley, 2010)

2.8 Harvesting and Storage

Harvesting equipments are employed to harvest soybeans. In harvesting, care is taken to minimize breaking or cracking of the beans. The same care should be observed when sending the beans to storage. The beans must be stored in conditions that will prevent the soybeans from insect infestations. Both the beans and the container should be clean and dry. In general, potential insect infestations could be averted with proper harvesting, loading and storage practices. Use of

insecticides is not advised for two reasons; it is an added expense and there are few recommended insecticides available for this (Knezevic *et al.*, 2003a). Harvest losses and mechanical damage may be high when soybeans are harvested below 12% moisture content. A loss of just 4 beans/9m^2 represents an overall loss of 67kg/ha. Losses can be minimized if a ground speed of 4-5km/h is maintained. The reel speed should be adjusted to match crop conditions. Combine harvesters, cutterbars, chaffers and sieves are used to harvest the matured beans from the field. The three major factors affecting the storability of soybeans are moisture content, temperature and distribution of storage. The general condition of the product and amount of foreign materials also affect storability (Knezevic *et al.*, 2003b)

Soybeans are usually traded on a 13% moisture basis, so it is to the farmer's advantage to harvest, store, and sell soybeans as close to 13% moisture (wet basis) as possible. Soybeans that are wetter than 13% moisture are likely to mould under warm conditions and buyers usually apply shrink factors and drying charges when wet beans are delivered. On the other hand, Soybeans that are drier than 13% moisture are more likely to split during handling and since they weigh less, fewer bushels are available for sale. If the storage temperature is kept below 16°C, soybeans can usually be held for at least six months; however, the recommended moisture content is 11% (Wilcke and Morey, 2004). Soybeans are subject to splitting during handling, so they are to be handled gently. Belt conveyors, bucket elevators, and drag or mass conveyors provide the greatest handling. Normal grain augers can be used it they are operated slowly. Avoid long drop heights in bean handling by frequently adjusting the position of conveyors or by using bean ladders or other devices that break long drops into series of shorter drops (Shibles and Weber, 1996)

2.9 Utilization

G. max can produce at least twice as much protein per acre than any other major vegetable or grain crop, 5 to 10 times more protein per acre than land set aside for grazing animals to make milk, and up to 15 times more protein per acre than land set aside for meat production. The beans contain significant amounts of phytic acid, alpha – linolenic acid and isoflavones (Genistein and Daidzein) (National Soybean Research Laboratory, 2010).

Together, oil and protein content account for about 60% of dry soybeans by weight; protein at 40% and oil at 20%. The remainder consists of 35% carbohydrate and about 5% ash. Soybean

cultivars comprise approximately 8% seed coat or hull, 90% cotyledons and 2% hypocotyls axis or germ. Soy protein is a relatively heat – stable storage protein. This heat stability enables soy food products requiring high temperature cooking, such as "tofu", "soy milk" and textured vegetable protein" (soy flour) to be made (Henkel, 2000). The principal soluble carbohydrates of mature soybeans are the disaccharide sucrose (range 2.5 – 8.2%), the trisaccharide raffinose (0.1 – 1.0%) composed of one sucrose molecule connected to one molecule of galactose, and the tetrasaccharide starchyose (1.4 to 4.1%) composed of one sucrose connected to two molecules of galactose. While the oligosaccharides, raffinose and stachyose, protect the viability of the soybean seed from desiccation, they are not digestible sugars and therefore, contribute to flatulence and abdominal discomfort in humans and other monogastric animals; undigested oligosaccharides are broken down in the intestine by native microbes producing gases such as carbon dioxide, hydrogen and methane. Since soluble soy carbohydrates are broken down during fermentation, soy concentrate, soy protein isolates, tofu, soy sauce, and sprouted soybeans are without flatus activity. On the other hand, there may be some beneficial effects to ingesting oligoosaccharides (Raffinose and stachyose) such as; encouraging indigenous bifidobacteria in the colon against putrefactive bacteria.

The insoluble carbohydrates in soybeans consist of the complex polysaccharides (cellulose, hemicellulose, and pectin). The majority of soybean carbohydrates can be classed as belonging to dietary fibre. (The American Soybean Association, 2008).

G. max must be cooked with "wet" heat in order to destroy the trypsin inhibitors (serine protease inhibitors). This is why raw soybeans are toxic to humans, swine, chickens, in fact, all monogastric animals (Circle *et al.,* 1972). *G. max* is considered by many agencies to be a source of complete protein (Henkel, 2000). A complete protein is one that contains significant amounts of all the essential amino acids that must be provided to the human body because of the body's inability to synthesize them. For this reason, soy is a good source of protein, amongst many others, for vegetarians and vegans or for people who want to reduce the amount meat they eat. Soy protein products can be good substitutes for animal products because, unlike some other beans, soy offers a 'complete' protein profile, soy protein products can replace animal – based foods (which also have complete protein but tend to contain more fat, especially saturated fat) without requiring adjustment elsewhere in the diet (Henkel, 2000).

G. max can be broadly classified as 'vegetable' [Garden] or 'oil' [field] types. Vegetable types cook more easily, have a mild mutty flavour, better texture, are larger in size, higher in protein, and lower in oil than field types. The 'garden' cultivars are generally not suitable for mechanical combine harvesting because there is a tendency for the pods to shatter upon reaching maturity.

Among the legumes, the soybean, also classed as an oil seed, is pre-eminent for its high protein content [40%] as well as its high oil content [20%]. Soybeans are the second most valuable agricultural export in the United State behind corn. The bulk of the soybean crop is grown for oil production, with a high –protein defatted and 'toasted' soybean used as livestock feed. A smaller percentage of soybeans are used directly for human consumption. Immature soybean may be boiled whole in their green pod and served with salt in Japan. In China, Japan and Korea the bean and products made from the bean are a popular party the diet. The Japanese foods made from soya include; 'miso', 'natto', 'kinako' and 'edamame'. In korean cuisine, soybean sprouts, called 'kongnamul', are also used in a variety of dishes, and are also the basic ingredients used to make soybean paste. The beans can be processed in a variety of ways. Common forms of soy-based foods include; soy meal, soy flour, soymilk, tofu, textured vegetable protein [TVP -- which is made into a wide variety of vegetarian foods, some of them intended to imitate meat], tempeh, soy lecithin and soybean oil. Soybeans are also the primary ingredients involved in the production of soy sauce (Fernandez-Cornejo and Caswell, 2006).

Soybean seed contains about 20% oil. To extract soybean oil from seed, the soybeans are cracked, adjusted for moisture content, rolled into flakes and solvent – extracted with commercial hexane. The oil is then refined blended for different applications, sometime hydrogenated. Soybean oils, both liquid and partially hydrogenated are exported abroad, sold as 'vegetable oil', or end up in a wide variety of processed foods. The remaining soybean meal is used mainly as animal feed.

Soybean can be processed to produce a texture and appearance similar to many other foods. For example, soybeans are the primary ingredient in many diary product substitutes (e.g. soy milk, margarine, soy ice - cream, soy yogurt, soy cheese and soy cream cheese) and meat substitutes (e.g. veggie burgers). These substitutes are readily available in most supermarkets. Soy milk does not naturally contain significant amounts of digestible calcium. Many manufactures of soy milk sell calcium - enriched products as well. Soybean is also used in "tempeh", beans (sometime mixed with grain) fermented into a solid cake. Soy products also are used as a low cost substitute in meat and poultry products (Merritt and Jenks, 2004; Joseph, 2001). Food service, retail and institutional (primary school lunch and correctional) facilities regularly use such "extended" products. Extension may result in diminished flavour, but fat and cholesterol are also reduced in the process. Vitamin and mineral fortification can be used to make soy products nutritionally equivalent to animal protein; although, the protein quality is already roughly equivalent. The soy – based meat substitute, TVP, has been used for more than 50 years as a way of inexpensively extending ground beef for

hamburgers, without reducing its nutritional valve, (Mian, 2006; National Soybean Research Laboratory, 2010; Circle and Smith, 1972; Liu, 1997).

Soybeans are used in industrial products such as; oils, soap, cosmetics, resins, plastics, inks, crayons, solvents, and clothing. Soybean oil is the primary source of biodiesel in the United States, accounting for 50% of domestic biodiesel production (National Biodiesel Board, 2008). Soybean has also been used since 200l as fermenting stock in the manufacture of a brand of vodka (Sacks *et al.*, 2006). During World War I, soybeans became importance in both North America and Europe, serving as organic fertilizer. (Raj, 2008; Reynold, 1962]

In 2005, top soybeans exporters were Brazil (39% of world soybean exports), United States (37%) and Argentina (16%), while top importers are China (41% of world soybean imports), European Union (22%), Japan (6%) and Mexico (6%) (Baohui *et al.*, 2007). The main producer of soybeans is the United States (32%), Brazil (28%), Argentina (21%), China (7%) and India (4%) (The American Soybean Association, 2008; FAO, 2007)

CHAPTER THREE

MATERIALS AND METHOD

3.1 Collection of materials

The soybean seeds used for this research were collected from Agricultural Development Programme (ADP), Akure, Ondo State. The seeds had been treated a year earlier at ADP with *Aframomum danielli* (Alligator pepper, a botanical insecticide) to prevent insect infestation. The seeds were first separated into two categories; the wholesome and the damaged. This is because wholesome seeds are obviously more viable than damaged ones. Sixty horticultural pots (38cm x 34.5cm in diameter and height respectively) were also collected from ADP, into which rich loamy soil was filled to near brim. The top soil was gotten from a piece of farmland behind the School of Science (SOS), FUTA. A screen house made of wooden frames and net, with a dimension of 3.65m x 3.04m x 2.13m (i.e. L x B x H) was constructed in order to protect the seedlings from voracious defoliators (mostly grasshoppers). The wooden frames of the screen house were painted with discarded engine oil in order to prevent termites from damaging the structure over time. The screen house was erected behind the SOS building and the foot/base was grounded into the earth firmly so as to withstand environmental pressures (such as heavy rainfall and strong winds)

3.2 Experimental Procedure

The sixty horticultural pots filled with top soil were arranged neatly inside the screen house, in such a way that ample working and walking distance between rows and columns was made available. Ten soybean seeds (wholesome ones) were planted into each horticultural pot. It was ensured that the sowing depth was not beyond 3mm, so that the seeds would not die or experience belated emergence. The pots were watered to field capacity every evening or every other day. When watering, the water was not poured directly unto the soil but sprinkled with the fingers in order to prevent water logging in one area of the pot or the burial of the seeds further down into the soil, thereby, preventing early emergence.

A week after planting, the treatment was applied. The sixty horticultural pots comprise three treatments (of fifteen replicates each) and a control (also of fifteen replicates). The replicates for the control were thinned to one seedling each, the replicates for treatment 1 were thinned to four seedlings each, the replicates for treatment 2 were thinned to six seedlings each and that for

treatment 3 were thinned to eight seedlings each. The visual observation of the experimental set up was done daily. Weeding was carried out daily.

After experimental set up, the seedlings were given two weeks to establish. Twenty-one days (3weeks) after planting, analysis on seedling growth and yield were carried out using the following parameters; Shoot Height, Root Length, Total number of leaves, Leaf Area and Total Plant Biomass. The analysis was done weekly for five weeks and three replicates per treatment (including the control) were harvested randomly for proper analysis.

3.3 Data Analysis

3.3.1 Physical Measurement

- Shoot Height; It was the distance between the soil level and the apex of the main stem.
- Root Length; It was the distance between the soil level and the tip of the tap root.
- Leaf Area (LA); This was done by measuring the length (L) and width (W) of the terminal leaflet and multiplying the product with the leaf shape correction factor (0.75), i.e., L x W x 0.75. The result is then multiplied by 3 (according to Nangju and Wanki, 1980) to obtain the LA for a trifoliolate leaf, i.e., LA/plant = L x W x 0.75 x 3

  Where 0.75 is the correction factor for leaf shape

  3 is the correction factor for a terminal leaflet of a trifoliolate leaf to obtain the true LA for the three leaflets.

- Total number of leaves; The number of leaflets per plant is determined and recorded as leaves.
- Total plant biomass; Three replicates per treatment and control were analysed weekly. Each individual in a replicate was treated equally.
  - The shoot was cut neatly with a scissors separating it from the root.
  - The shoot and root were deposited into different labeled brown envelopes (22.9cm long and 10.1cm wide) and transferred into a Gallenkamp Drying Cabinet MD3600.

- The 114 brown envelopes (the amount used per week) containing 57 shoots and 57 roots were dried in the cabinet at a temperature of 60°C to constant weight.
- A thermometer was dipped into the cabinet per time to ascertain the actual temperature generated within the cabinet if it's in line with the required temperature.
- After drying, the envelopes were removed from the drying cabinet and the contents were weighed using a Mettler Toledo PB3002 weighing balance.
- The shoot and root weights are then added together to determine the total biomass per plant.

3.3.2 Statistical Analysis

The confidence limit of all data was set by F. Distribution test at 95% probability. All the data obtained in the experiment were subjected to analysis of variance (ANOVA) using the Duncan test as a post-hoc test.

CHAPTER FOUR

RESULT

4.1 Effect of Intraspecific Competition on Shoot Height

Three weeks after planting, plant density was directly proportional to shoot height, with treatment 3 having the best performance (17.83cm) and the control having the least (14.16cm). A week later, treatment 1 (22.30cm) replaced treatment 3 (21.02cm) as the best and the control remained as the least (20.53cm). Five weeks after planting, treatment 2 (31.10cm) replaced treatment 1 (28.95cm) as the best , while treatment 3 (25.50cm) showed the poorest performance. On the sixth week, treatment 3 (34.90cm) performed best while the other treatments showed slight differences. Seven weeks after planting, treatment 1 (45.67cm) had the best growth followed by treatment 2 (41.88cm), control (40.76cm) and treatment 3 (38.89cm). The result of the effect of intraspecific competition on seedling shoot height in *G. max* is shown in Fig.1 below.

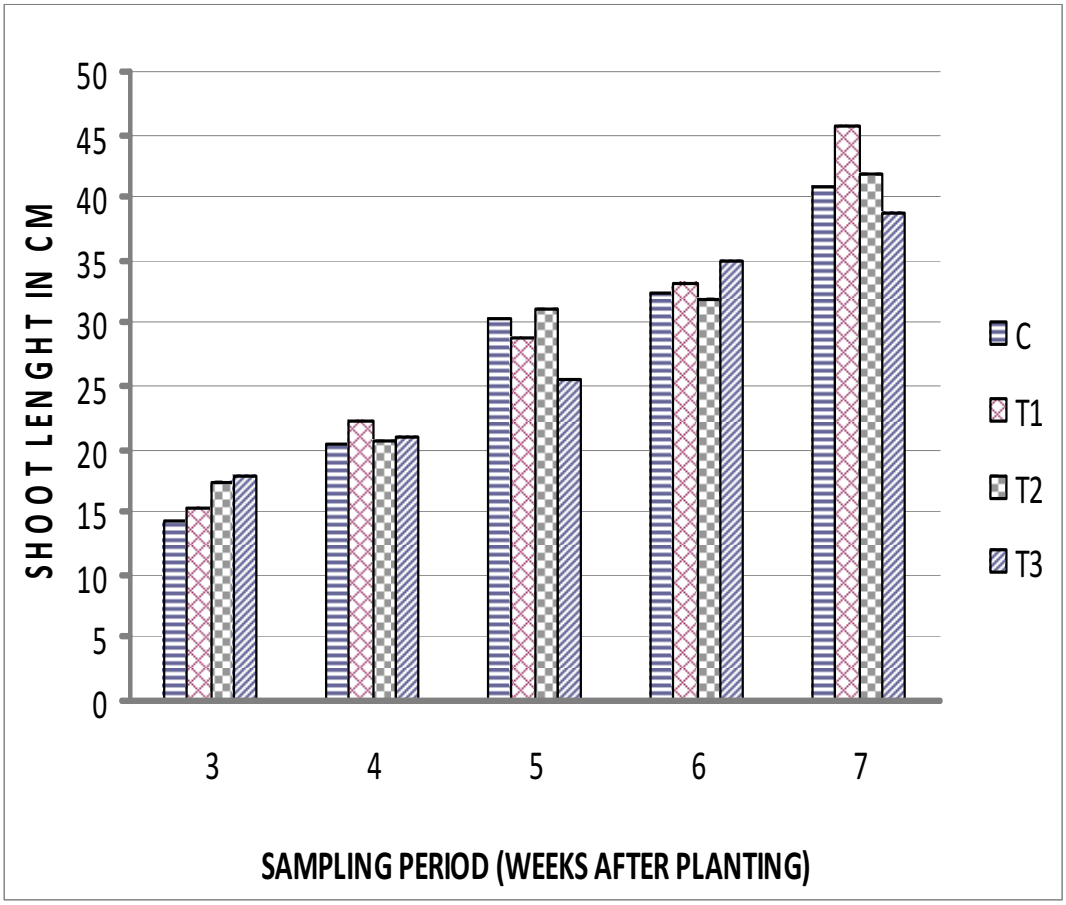

Fig.1; The effect of intraspecific competition on seedling shoot height

C- Control

T1- Treatment 1

T2- Treatment 2

T3- Treatment 3

4.2 Effect of Intraspecific Competition on Root Length

Three weeks after planting, the control showed tremendous root development (47.33cm) despite its poor growth in terms of shoot height. Treatment 1 showed the poorest root development (36.51cm). A week later, treatment 2 (50.11cm) replaced the control (47.36cm) as the most

developed, while treatment 3 (44.35cm) replaced treatment 1 (49.91cm) as the least developed. Treatment 1 and 2 had approximately equal root development at this stage. Five weeks after planting, plant density appeared to be inversely proportional to root length. The control (76.50cm) had a highly impressive growth which outshone the other treatments (55.17cm, 52.49cm, and 44.37cm respectively). On the sixth week, the control (87.460cm) retained its outstanding performance and by the seventh week, treatment 1 (69.51cm) took over from the control (67.33cm). The result of the effect of intraspecific competition on seedling root length in G. max is shown in Fig.

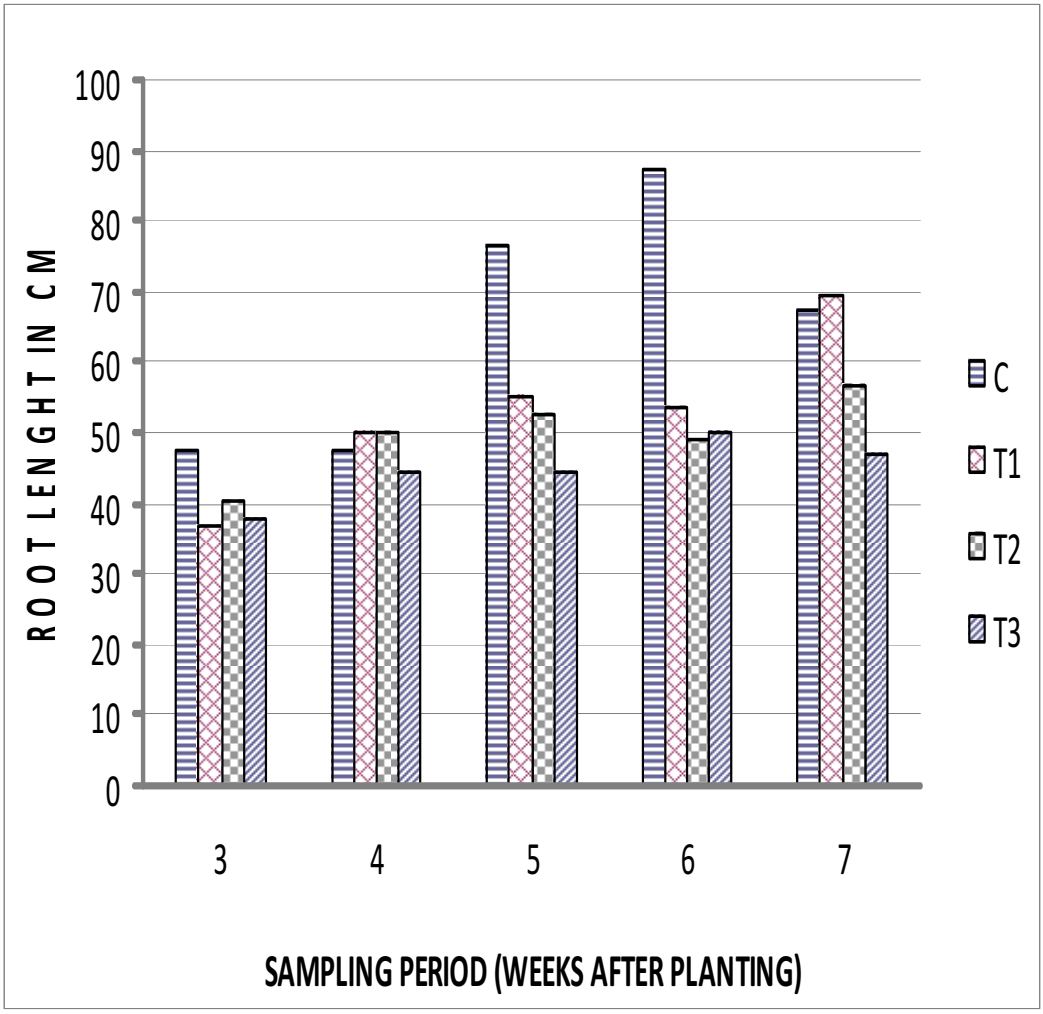

Fig.2; The effect of intraspecific competition on seedling root length in *G. max*

4.3 Effect of Intraspecific Competition on Number of Leaves

Three weeks after planting, the control, treatment 1, treatment 2, treatment3, all had relatively equal amount of leaves. On the fourth week, the number of leaves appeared to be inversely

proportional to plant density. On the fifth week, the control showed superiority while treatment 1 and 2 had approximately equal number of leaves. On the sixth and seventh week after planting, the number of leaves continued to show an inverse relationship to plant density with the control outshining the treatments in both weeks. The result of the effect of intraspecific competition on the number of seedling leaves in *G. max* is shown in Fig.3 below.

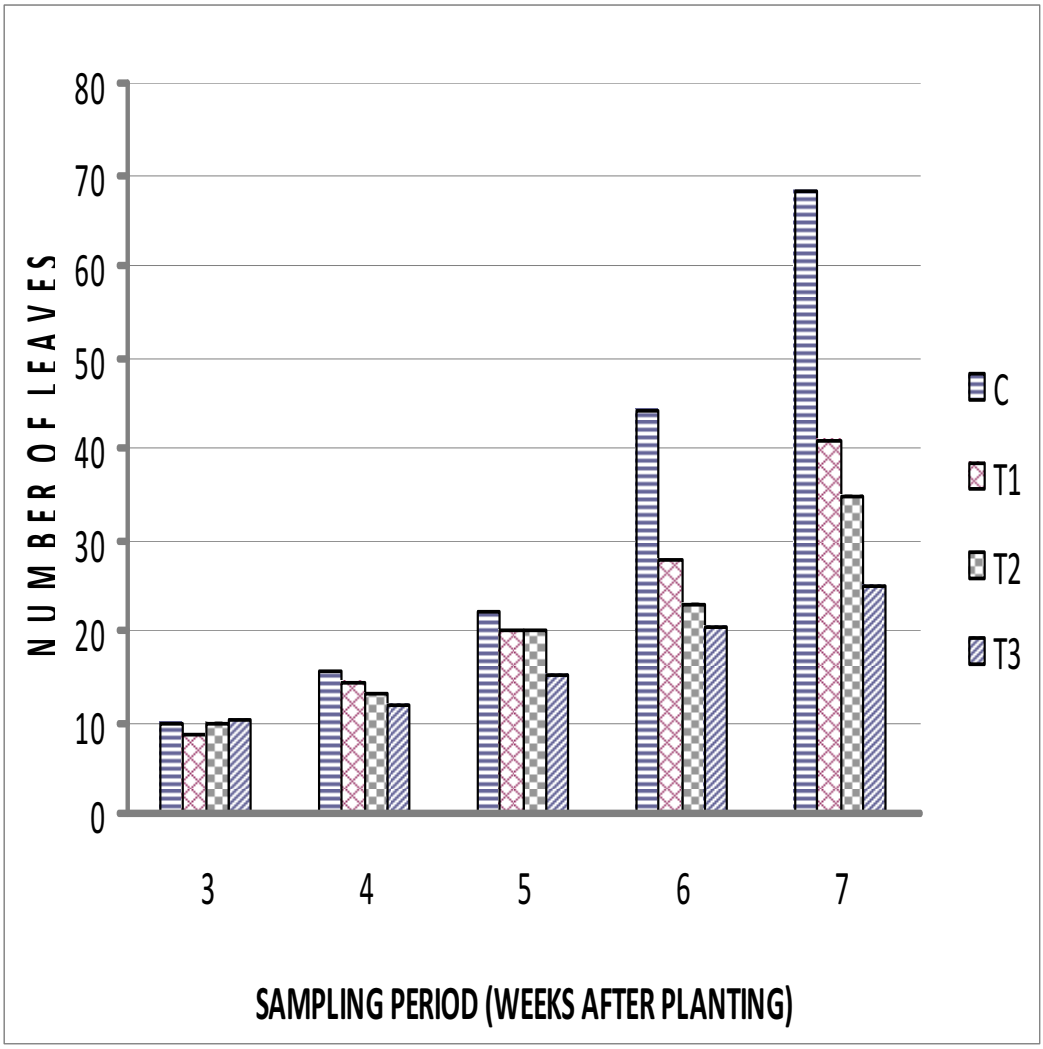

Fig.3; The effect of intraspecific competition on the number of seedling leaves in *G. max*

4.4 Effect of Intraspecific Competition on Leaf Area

Three weeks after planting, treatment 3 had the largest leaves ($0.29m^2$), treatment 2 had ($0.27m^2$) had a similar performance while the control ($0.24m^2$) trailed behind. A week later, treatment 1 ($0.44m^2$) and control ($0.43m^2$) were slightly equal while treatment 3 ($0.32m^2$) lost its initial superiority. Five weeks after planting, the control ($0.90m^2$) outshone the treatments ($0.65m^2$,

0.66m^2 and 0.50m^2 respectively). On the sixth week, treatment 1 (0.74m^2) showed a slightly better performance than the control (0.73m^2) while treatment 2 and 3 had equal performance (0.63m^2 each). On the seventh week, the control (0.90m^2) showed superiority over the treatments (0.84m^2, 0.75m^2 and 0.59m^2 respectively). Leaf area appeared to be inversely proportional to plant density. The result of the effect of intraspecific competition on seedling leaf area in *G. max* is shown in Fig.4 below.

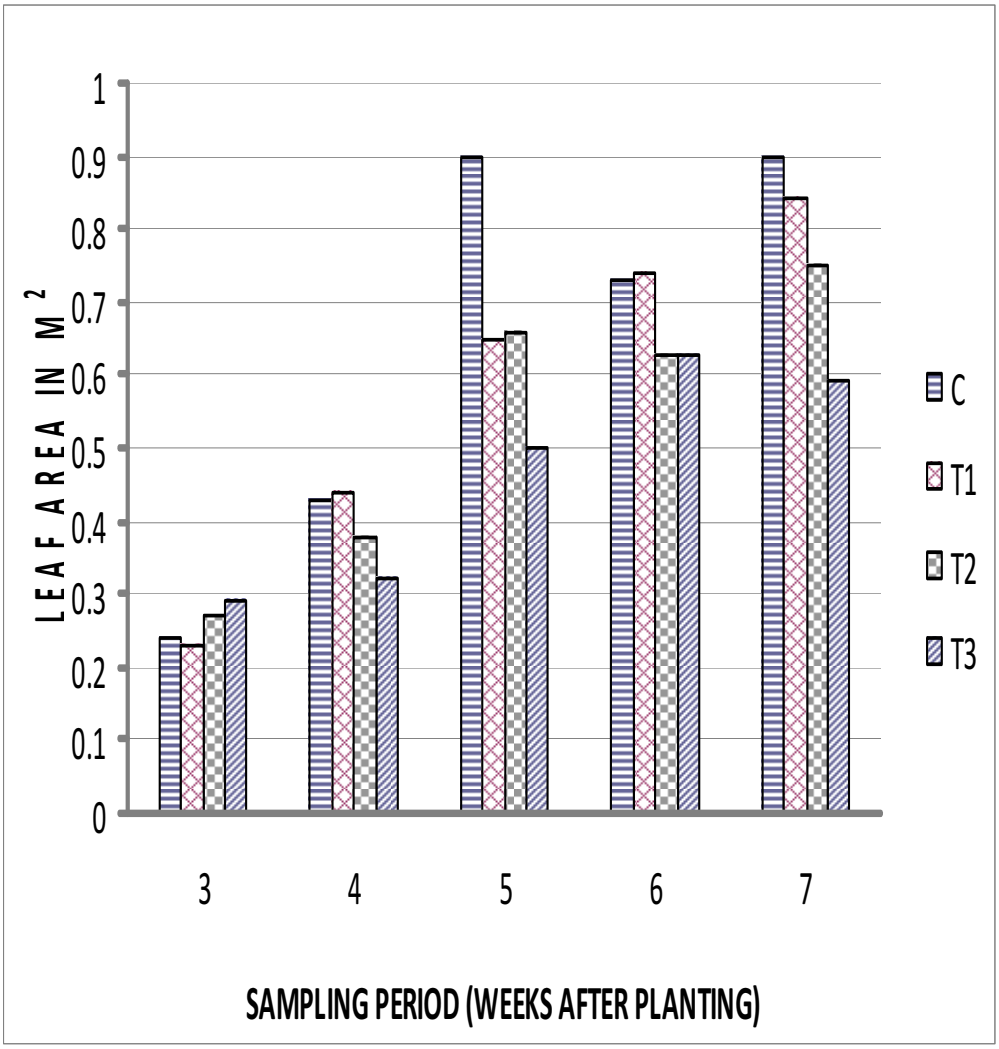

Fig.4 The effect of intraspecific competition on seedling leaf area in *G. max*

4.5 Effect of Intraspecific Competition on Total Plant Biomass

Three weeks after planting, treatment 3 and 2 (0.68g and 0.61g respectively) performed better the control (0.50g). Four weeks after planting, the control (1.38g) performed better than the treatments with treatment 3 (0.88g) having the least performance. On the fifth week, the control was the most impressive (3.80g) while treatment 2 followed with 3.05g. Six weeks after planting, the control had the highest mass (7.66g) followed by treatment 1 (5.00g), while treatment 2 and 3 had approximately equal masses (3.26g and 3.32g respectively). On the seventh week, the control

(15.86g) showed superiority over the treatments (8.12g, 6.00g and 4.19g respectively). Total plant biomass appeared to be inversely proportional to plant density. The result of the effect of intraspecific competition on total plant biomass in *G. max* is shown in Fig.5 below.

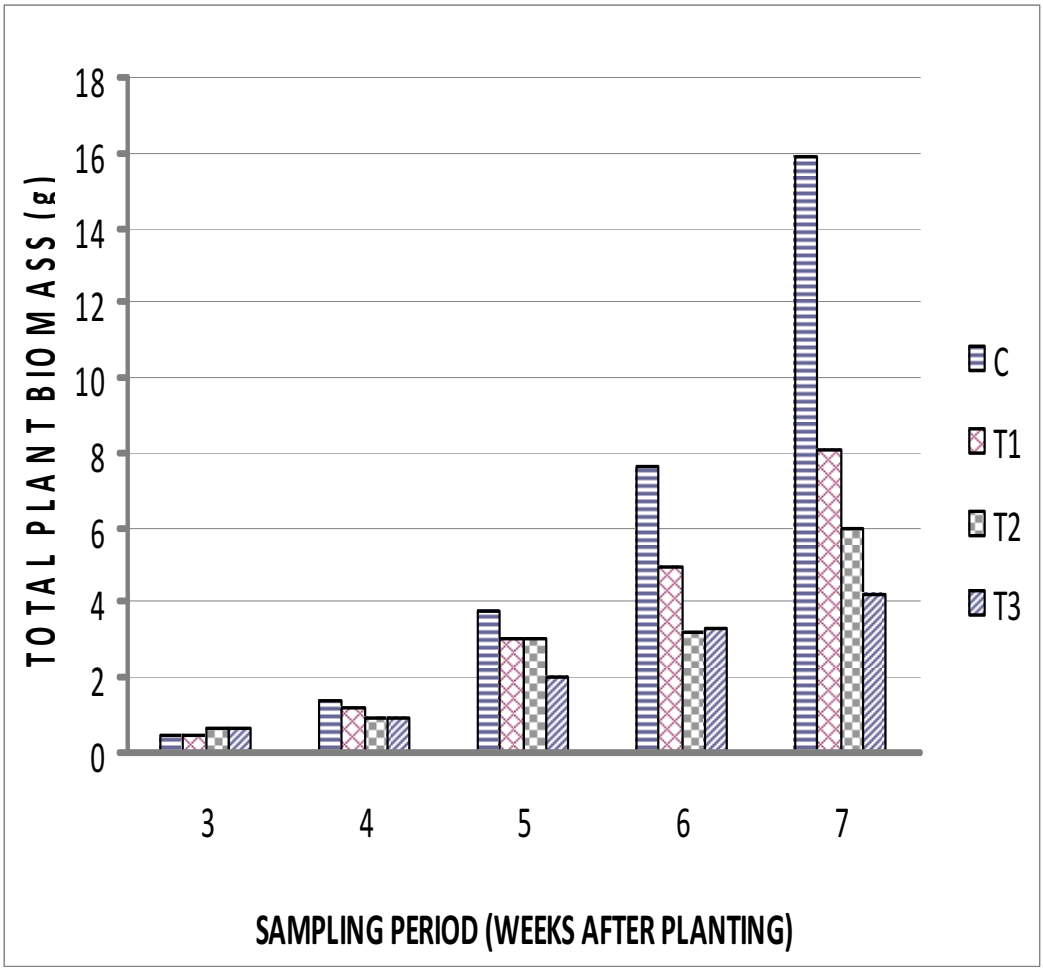

Fig.5; The effect of intraspecific competition on total plant biomass in *G. max*

CHAPTER FIVE

DISCUSSION

5.1 Effect of Intraspecific Competition on Shoot Height

Fig.1 showed that the treatments with higher densities performed better than the control in terms of shoot height. Despite the growth difference on the field, Appendix 1b shows that there is no significant difference ($P>0.05$) among the treatments (including the control) in terms of shoot height, although there was significant difference ($P<0.05$) within the sampling periods. Changes in the environment such as temperature and rainfall can greatly alter the height of soybeans without a large effect on early reproductive stages such as flowering. Therefore, soybean development is best analysed via other growth parameters rather than considering the height (Naeve, 1980). According to Barrentine and Saley (2003), soybean plant height is not significantly influenced by the row spacing. Therefore, intraspecific competition had no tangible effect on the shoot height of soybeans.

5.2 Effect of Intraspecific Competition on Root Length

It should be noted that the radicle and plumule develops concurrently, although, in soybeans the root is highly diffuse and branching compared to the shoot. It was reported that when tall morning glory was planted with soybeans, soybeans were more competitive than tall morning glory for the first six to eight weeks after emergence. Tall morning glory was three to four times more competitive during the soybean reproductive stage (about eight weeks after planting) than during the vegetative stage (Weed Science Society of America, 1976). This account for the aggressive growth rate observed in soybeans in terms of root length (and even shoots height and number of leaves). Soybeans are highly competitive when planted in high densities (whether in a mixed culture or a monoculture). Appendix 2a shows that there is significant difference ($P<0.05$) between the control and the treatments as from the fifth week after planting.

5.3 Effect of Intraspecific Competition on Number of Leaves

Considering the competitive nature of soybeans especially during their vegetative period, it should not be surprising to find them flourishing in terms of number of leaves. Soybean and common waterhemp (*Amaranthus rudis*) was investigated under weed densities. The soybean leaflet number were measured over forty-five day period and used to calculate the growth rate. Soybean leaflet number differed significantly ($P<0.05$) according to waterhemp density (Pfeiffer *et. al.,* 2008). Appendix 3a, shows that there was significant difference

($P<0.05$) between the control and the treatments and also among the treatments as from the fifth week after planting.

5.4 Effect of Intraspecific Competition on Leaf Area

Plant density strongly affects leaf area, and therefore, light interception and canopy photosynthesis in soybeans is a major concern in mixed cultures and monocultures (Stulen *et. al.,* 2002). Hunter (1980) concluded that a larger leaf area per plant produced more assimilate in the plant , resulting in increased yield. Pepper (1974) reported that increased plant densities can promote utilization of solar radiation by canopies. However, efficiency of conversion of intercepted solar radiation into economic yields will decrease with high population density because of mutual shading of plants (Buren, 1970). Appendix 4a shows that five weeks after planting and seven weeks after planting, the control was significantly different ($P<0.05$) from the treatments revealing the negative effect of density on leaf area.

5.5 Effect of Intraspecific Competition on Total Plant Biomass

Soybean aggressivity decreased with weed density (*Anoda cristata*) in both narrow-row and wide-row spacings. Soybean yield loss at harvest was linearly related to relative dry weight after planting (Barrentine and Saley, 2003). Fig. 5 showed that total plant biomass was inversely proportional to plant density. Therefore, intraspecific competition had a great effect on biomass. Appendix 5b shows that total plant biomass had a significant difference ($P<0.05$) on the treatments and within the sampling periods.

5.6 Conclusion

It appears that the effect of intraspecific competition on seedling growth in soybeans varies significantly depending on the growth parameter considered. The least reliable growth parameter appears to be the shoot height whilw the most reliable appears to be the leaf area and biomass. Also, intraspecific competition can be used efficiently to manage weeds. Yunusa and Ikawelle (2008) reported that soybean has a yield advantage with moderately high planting densities and narrow spacing. Danaeifer *et. al*. (2001) also reported that with the rise of density, the dry matter produced

in both sole cropping (monocultures) and intercropping increased. The high plant density particularly as to forage crops, creates a suitable microclimate and results in the rise of total dry matter yield.

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Appendices

1a Shoot Height (cm) of *Glycine max* in horticultural pots sown at four different densities. Values are means ± standard error.

Treatment/Density	**Sampling period (Weeks after planting)**				
	3	4	5	6	7
Control (1 Seedling/pot)	14.16[a] ± 1.85	20.53[a] ±0.23	30.33[a]±1.85	32.36[a]±6.40	40.76[ab]±3.37
T_1 (4 Seedlings/pot)	15.20 [a] ±0.57	22.32 [a] ±0.89	28.95 [a] ±3.10	33.09 [a] ±2.21	48.17 [b]± 2.79
T_2 (6 Seedlings/pot)	17.34 [a] ±1.19	20.69 [a] ±0.70	31.10 [a] ±1.07	31.82 [a] ±2.67	41.88 [a b]±1.67
T_3 (8 Seedlings/pot)	17.48 [a] ± 1.02	21.02 [a] ±0.45	25.50 [a] ±2.19	34.90 [a] ±2.04	38.89 [a] ±2.24

***values with the same alphabet within the same column are not significant (P>0.05)**

1b: **Analysis of Variance Table for data in appendix 1a**

Sources of variation	**df**	**SS**	**MS**	**F**	**Sig.**
A (Treatment)	3	39.299	13.100	0.786	0.509
B (Sampling period)	4	5086.027	1271.507	76.260	0.000
A*B	12	207.946	17.329	1.039	0.434

2a Root Length (cm) of *Glycine max* in horticultural pots sown at four different densities. Values are means ± standard error.

Treatment/Density	**Sampling period (Weeks after planting)**				
	3	4	5	6	7
Control (1 Seedling/pot)	$47.33^{a} \pm 1.24$	$47.36.^{a} \pm 1.44$	$76.50^{b} \pm 1.07$	$87.46^{b} \pm 7.44$	$67.33^{bc} \pm 3.49$
T_1 (4 Seedlings/pot)	$36.51^{a} \pm 4.49$	$49.91^{a} \pm 1.95$	$55.17^{a} \pm 0.12$	$53.32^{a} \pm 2.08$	$69.51^{c} \pm 3.60$
T_2 (6 Seedlings/pot)	$40.31^{a} \pm 3.60$	$50.11^{a} \pm 1.91$	$52.49^{a} \pm 4.68$	$48.81^{a} \pm 2.22$	$56.84^{a\,b} \pm 3.30$
T_3 (8 Seedlings/pot)	$37.96^{a} \pm 1.74$	$44.35^{a} \pm 3.30$	$44.37^{a} \pm 1.98$	$48.02^{a} \pm 1.27$	$46.69^{a} \pm 2.90$

***values with the same alphabet within the same columnare not significant (P>0.05)**

2b: **Analysis of Variance Table for data in appendix 2a**

Sources of variation	**df**	**SS**	**MS**	**F**	**Sig.**
A (Treatment)	3	3551.496	1183.8	11.713	0.000
B (Sampling period)	4	3362.480	840.620	8.317	0.000
A*B	12	2727.247	227.271	2.249	0.028

3a Number of Leaves of *Glycine max* in horticultural pots sown at four different densities. Values are means ± standard error.

Treatment/Density	**Sampling period (Weeks after planting)**				
	3	4	5	6	7
Control (1 Seedling/pot)	$10.00^{a} \pm 1.00$	$15.66^{a} \pm 3.66$	$22.00^{b} \pm 2.64$	$44.00^{b} \pm 1.11$	$68.00^{a} \pm 2.40$
T_1 (4 Seedlings/pot)	$8.33^{a} \pm 0.33$	$14.33^{a} \pm 0.33$	$20.00^{ab} \pm 1.73$	$28.00^{ab} \pm 0.57$	$41.00^{a} \pm 4.58$
T_2 (6 Seedlings/pot)	$9.66^{a} \pm 0.33$	$13.00^{a} \pm 0.00$	$20.00^{ab} \pm 1.15$	$24.33^{b} \pm 0.66$	$35.00^{a} \pm 2.30$
T_3 (8 Seedlings/pot)	$10.33^{a} \pm 0.33$	$12.33^{a} \pm 0.66$	$15.33^{a} \pm 1.45$	$21.66^{a} \pm 0.88$	$27.00^{a} \pm 3.46$

***values with the same alphabet within the same column are not significant (P>0.05)**

3b: **Analysis of Variance Table for data in appendix 3a**

Sources of variation	**df**	**SS**	**MS**	**F**	**Sig.**
A (Treatment)	3	1786.800	595.600	5.159	0.004

B (Sampling period)	4	8517.500	2129.375	18.44	0.000
A*B	12	2059.700	171.642	1.487	0.170

4a Leaf Area (m^2) of *Glycine max* in horticultural pots sown at four different densities. Values are means ± standard error.

Treatment/Density	**Sampling period (Weeks after planting)**				
	3	4	5	6	7
Control (1 Seedling/pot)	$0.23^{a} \pm 0.01$	$0.43^{a} \pm 0.11$	$0.90^{b} \pm 0.06$	$0.73^{a} \pm 0.12$	$0.90^{c} \pm 0.02$
T_1 (4 Seedlings/pot)	$0.23^{a} \pm 0.02$	$0.44^{a} \pm 0.02$	$0.64^{a} \pm 0.02$	$0.74^{a} \pm 0.02$	$0.83^{bc} \pm 0.01$

T_2 (6 Seedlings/pot)	$0.27^{a} \pm 0.01$	$0.38^{a} \pm 0.02$	$0.65^{a} \pm 0.05$	$0.63^{a} \pm 0.03$	$0.74^{b} \pm 0.04$
T_3 (8 Seedlings/pot)	$0.29^{a} \pm 0.02$	$0.32^{a} \pm 0.03$	$0.49^{a} \pm 0.05$	$0.62^{a} \pm 0.06$	$0.59^{a} \pm 0.04$

***values with the same alphabet within the same column are not significant (P>0.05)**

4b: **Analysis of Variance Table for data in appendix 4a**

Sources of variation	**df**	**SS**	**MS**	**F**	**Sig.**
A (Treatment)	3	0.249	0.083	10.181	0.000
B (Sampling period)	4	2.293	0.573	70.333	0.000
A*B	12	0.248	0.021	2.535	0.014

5a Total Plant Biomass (g) of *Glycine max* in horticultural pots sown at four different densities. Values are means ± standard error.

Treatment/Density	**Sampling period (Weeks after planting)**				
	3	4	5	6	7
Control (1 Seedling/pot)	$0.50^{a} \pm 0.02$	$1.38^{a} \pm 0.71$	$3.80^{b} \pm 0.49$	$7.66^{b} \pm 0.50$	$15.86^{b} \pm 4.23$
T_1 (4 Seedlings/pot)	$0.44^{a} \pm 0.03$	$1.23^{a} \pm 0.14$	$3.02^{a} \pm 0.38$	$5.00^{b} \pm 0.52$	$8.12^{a} \pm 0.52$
T_2 (6 Seedlings/pot)	$0.61^{b} \pm 0.01$	$0.96^{a} \pm 0.04$	$3.05^{a} \pm 0.01$	$3.26^{a} \pm 0.02$	$6.00^{b} \pm 0.58$
T_3 (8 Seedlings/pot)	$0.68^{a} \pm 0.04$	$0.88^{a} \pm 0.06$	$2.01^{a} \pm 0.57$	$3.32^{a} \pm 0.02$	$3.87^{a} \pm 0.41$

***values with the same alphabet within the same column are not significant (P>0.05)**

5b: **Analysis of Variance Table for data in appendix 5a**

Sources of variation	**df**	**SS**	**MS**	**F**	**Sig.**
A (Treatment)	3	116.808	38.936	7.624	0.000
B (Sampling period)	4	491.605	122.901	24.067	0.000
A*B	12	173.067	14.422	2.824	0.007

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