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Effect of Three intra-rows spacing (50cm, 25cm and 10cm) on Growth, Yield and Biological Characteristics of Senna obtusifolia: A Plant for Economic Diversification in Tropical Zone.

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Abstract: *The experiment was laid-down to evaluate the effect of three intra- rows spacing on growth, yield and biological characteristics of senna obtusifolia plant. Constant inter- row spacing (50cm) and three intra- rows spacing (50cm, 25cm and 10cm) were examined. There were four ridges for each treatment; all treatments were replicated three times in a randomized complete block design (RCBD). Data collected were subjected to analysis of variance (ANOVA) using IBM SPSS Statistics 20.0 version and treatment means were separated using Duncan Multiple Range Test (DMRT). It was observed that plant height, days to maturity, total seed yield, dry matter weight, number of pod and seed varied significantly ($p<0.05$) between the intra- rows spacing. Senna obtusifolia planted at wide intra-row spacing of 50cm plant to plant recorded significantly shortest days to maturity (158 days), maximum dry matter weight (177.1g/plant), highest number of pods (221/plant) and utmost total seed yield (5.63 tons ha-^{1}). However, narrow intra-row spacing of 10cm between plants prolonged maturity days (176 days), recorded minimum dry matter weight (49.4g/plant), least number of pods (32/plant) and intermediate total seed yield (4.0 tons ha-^{1}). Hence, it was concluded that senna obtusifolia plant should be planted at 50 cm intra-row spacing for maximum dry matter weight (livestock feed) and seed production to enhance profitability and economic diversification in tropical zone.*

Key words*: biological characteristics, tropical zone, intra-row, spacing, Senna obtusifolia, yield, economic, diversification, Fulani herdsmen, farmer, clashes.*

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I. Introduction

Senna obtusifolia (known as "Tafasa" in Sudan Savannah of Nigeria) belongs to the kingdom plantae, family fabaceae. A common annual plant grows wild in Sudan Savannah. The plant is considered a serious weed to agriculturists and farmers in Sudan Savannah and Tropical Zone in general. Senna obtusifolia is found throughout tropical Africa and it was introduced into Africa from America (Irwin and Barneby, 1982). The young tender leaves of Senna obtusifolia occasionally used as vegetable throughout Africa and the plant is cultivated in home for this purpose in several countries including Senegal, Ghana, Cameroon and Ethiopia. Older leaves if eaten frequently or in large quantities will cause diarrhea (Irwin and Barneby 1982). Phytochemical screening of Senna obtusifolia revealed that the extracts contained some phyto-constituents such as saponins, tannis, alkaloids and flavonoids are present in both the leaves and seeds. The high percentage of these phytochemicals in both plant leaves and seeds demands for processing before use as vegetable or livestock feed. The leaves could be cooked and roasting the seeds is necessary before use (Becker 1986). Ismaila (2011) reported that senna obttusifolia leaves contained 5.2% crude protein, 2.6 crude fibre, mineral elements such as calcium, sodium and some anti-nutritional factors. Along these lines, Abdulazeez, et al (2016) opined that replacing wheat offal with 30% dry senna obtusifolia generally increased feed consumption, growth and feed intake of the Chinchilla rabbits (herbivorous rodent) and considerable reduction in feed cost. He further recommended that Food and Agricultural Organization and World Health Organization should consider Senna obtusifolia as fodder (hay) for rabbits and ruminants and not notorious weed. Compared to other livestock green feed such as ground nut plant, senna obtusifolia plant can be established successfully in all soils including ranch and grazing lands (Holm et al, 1997). Retzinger (1983) recorded Senna obtusifolia seed production of 2800 to 8200 seeds/plant resulting in an enormous seed bank in the soil. Flowers first appear after 43 – 84 days depending on ecotype and climate. Pollen is released through the vibration of the flowers by bees (buzz pollination) and it is thought that self-pollination is probably the norm. The dehiscent pod can disperse seeds up to 5m, further dispersal can occur via wind, water or in mud attached to the feet or fur of animals, or to shoes and machinery. When ingested by cattle, horse or goats it may survive the passage of the gut. Senna obtusifolia have hard seed coats which need to be mechanically damaged to break dormancy (Becker, 1986). Seeds of Senna obtusifolia are harmful to livestock due to the presence of a trypsin inhibitor, but this is inactivated by boiling, which converts the seeds into a good source of protein (Cock and Evans, 1984). Senna obtusifolia is an herbaceous perennial or sub-shrub, spreading, 0.5 m tall. Leaves alternate 5-6 cm long including a channeled petiole 20-45 mm, leaflets in 2-3 pairs, obovate 25-55 mm long, 10-35 mm wide, obtuse/rounded. Inflorescence of 1-2 flowers, petals 8-10mm long, fertile stamens 10, fertile filaments 1.5-2.5 mm long, fertile anthers 1.5-2.5 mm long. Pod cylindrical 12-28 cm long, 2-5 mm diameter, curved. Seed dull or lustrous, Senna obtusifolia is commonly self-pollinated before the flower opens. The style is curved inward with the stigma cavity facing the anthers (Irwin and barneby 1982, Everest, Thomas and John 2016).

1.1 Fulani Herdsmen and Farmers Clashes in Nigeria.

Fulani herdsmen or Nomadic Fulani in Nigeria mostly keep cattle (White Fulani and Red Bororo breed) and sheep (Uda, Balami or Yankasa breed) and move from one ecological zone to another in search of green pasture to feed their livestock. This movement of livestock within the country has created lots of problem in Nigeria. According to Timi (2016), the frequent clashes between farmers and herdsmen in Nigeria have since assumed very dangerous dimensions with unimaginable consequences for the continued peaceful coexistence of the country. For about three years now, Adamawa, Benue, Kaduna, Nasarawa and Taraba states have continued to experience senseless destruction of lives and property of their innocent citizens by Fulani/Farmers clashes. The problems of livestock feeding in Nigeria seem not to be that of none availability of feed stuffs but none implementation of livestock-feed-research-results and inability to conserve forage green plants or hay. Embracing abundant Senna obtusifolia plant as animal feed is the permanent solution to Fulani herdsmen and farmer clashes in Nigeria. In Sudan savannah of Nigeria, between October 2015 and March 2016, 9 out of 233 senna obtusifolia naturally growing Local Government Areas informally exported 790 tons of senna obtusifolia seeds worth $246,875 (₦74,062,500.0) to other countries (Abdulazeez et al, 2016). Intra-row spacing is the distance between one senna obtusifolia plant and the other on the same bed or ridge. It was observed that among various package of improved plant production technology, proper plant population with appropriate adjustment row and plant distances play vital role in enhancing plant production. Research conducted with other legume species showed similar reactions to those of senna obtusifolia. Contrary to the potential for better yields, narrow row spacing may foster more optimal micro-climates for the spread of soybean diseases. Narrow row soybean planting can increase Sclerotinia stem rot disease development, whereas wide row planting resulted in decreased disease severity (Grau and Radke 1984). Stem rot disease severity was also lower when seed planting densities were reduced (Lee et al. 2005). More air movement and less soil/plant surface moisture within the canopy may the causes of reduced disease in certain soybean cultivars (Kim et al. 1999). The benefits of narrow-row spacing on weed management in soybean are mainly attributed to the early canopy closure in the soybean planted in narrow (19 or 38 cm wide) that enhances the competitive ability of the crop against weeds, compare to wide (76 cm or more) rows (Steckel and Sprague, 2004). Thus, the early canopy formation trait of narrow-row soybean can potentially reduce weed resurgence and reduce reliance on multiple post-emergence glyphosphate herbicide applications or cost of manual weeding in soybean. Plants that are close to each other may compete for nutrients and available sunlight for survival by growing tall (Ron, 2015). The effect of planting density on growth and yield of Senna obtusifolia was investigated by Kwon et al (1990). Four densities were tested, 60 cm x 30 cm, 60 cm x 15 cm, 30 cm x 15 cm and 30 cm x 10 cm. The seed yield per area was highest under the 60 cm x 15 cm spacing and declined under the lower and higher planting densities. The least optimal spacing (30 cm x 10 cm) yielded 1.6 t/ha while the optimal spacing (60 cm x 15 cm) yielded 2.1 t/ha, a 31% increase (Murphy et al. 1996). Spacing is not always significant in seed yields however, since a single larger, branching plant can yield as much seed as several smaller, single-stemmed plants. In trials of guar in india, planting density did not significantly affect seed, gum or protein yields per unit area (Malik et al. 1981). Details on cultivation of Senna obtusifolia in Africa are unknown. In India seeds for gum production are presently harvested from the wild. As far as is known, Senna obtusifolia is only grown commercially in Korea for medicinal uses, with seed yields as high as 2.6t/ha. Fertilizer applications of 80kgN, 30kg P and 50kg K were optimal for seed production. Seeds gums are used worldwide for a variety of industrial applications. Increased demand and inconsistency of supply and price has driven industrial users to search for new sources of supply and, senna obtusifolia is a good alternative for locust bean and guar gums (Burkill, 1995). Seed gums are classified as a 'thickener/vegetable gum' in foods and also used in a range of non-food applications including medicine, textile and paper manufacturing. The main sources of seed gums on the world market are locust bean and guar. An increasingly important gum is sourced from senna tora and senna obtusifolia in India, Australia and Korea (David and Kerry 2001).

1.2 Significance of the Experiment

Senna obtusifolia plant is utilized locally and internationally for a variety of reasons, particularly as food, livestock feed (fig. 1), medicine, export crop and means of economic diversification. In Sudan Savannah of Nigeria, the young leaves of senna obtusifolia are cooked to produce a delicacy called "Danbu Tafasa" (ingredients - young senna obtusifolia leaves, maize grains (2mm), ground nut cake (2mm), palm oil, salt and maggi, (fig. 2), and matured seeds are packed in sacks for export (fig. 3). Traditionally and commercially, senna obtusifolia is not grown in Nigeria, both the leaves and seeds are presently harvested from the wild. There is limited research conducted on the effect of intra – rows spacing on growth, yield and biological characteristics of senna obtusifolia. In considering the above facts, there is the need to search for appropriate agronomic intra-row spacing for senna obtusifolia plant; to enhance livestock feed production, further research, profitability and economic diversification in tropical countries. .

Fig. 1. Job opportunity; Sheep feeding on shade dried senna obtusifolia plants, harvested 84 days after planting.

Fig. 2. Job opportunity; Senna obtusifolia delicacy (Danbu Tafasa food) inside plate; ingredients - senna obtusifolia leaves, maize grains (2mm), ground nut cake (2mm), palm oil, salt and maggi. Plant leaves harvested 40 days after planting.

Fig. 3. Job opportunity; Senna obtusifolia seeds packed in sacks for export at Dawanau International market, Kano state, Nigeria. January 4, 2017.

1.3 Aim of the Experiment

The aim of the experiment is to assess the effect of three intra-rows spacing on growth, yield and biological characteristics of senna obtusifolia indigenous to Bichi.

1.4 Objectives of the experiment:

Specifically, the experiment sought to:

i. To determine the optimum intra-row spacing for Senna obtusifolia plant.
ii. To provide guideline on biological and agronomy of Senna obtusifolia.
iii. To introduce Senna obtusifolia as tropical economic plant and as a solution to Fulani herdsmen and farmers clashes in Nigeria.

1.5 Hypothesis

Ho: hypothesis is tested at 0.05 level of significant. There is no significant ($p>0.05$) difference in senna obtisifolia means total seed yield of the three intra-rows spacing.

II. Materials and Method

2.1. Materials

The materials employed for the experiment are: senna obtusifolia seeds, electronic balance, hot water, clock, cloth tape (200cm), hoe, cutlass, tractor, disc harrow and N.P.K. (15:15:15) fertilizer

2.2 Methods

2.2.1 Experimental Site and Field Management

Field experiment was conducted between June and November, 2017 at the Federal College of Education (T) Bichi, research area ($8^0$14'-$12^0$14'E and $12^0$14'-$14^0$13'N) in the Sudan Savannah zone of Nigeria. The soil type was loam sand with P^H 7.4 and organic matter 0.7%. The experiment area was prepared using combination of tractor mounted disk harrow and traditional hoe.

2.3. Experimental Design, Treatments and Crop husbandry.

Treatments consisted of three intra-rows spacing; narrow-row (10cm), medium-row (25cm) and wide-row (50cm) and constant inter-row spacing (50cm), the experiment was thoroughly monitored for over five months (figs. 4-9, table 1). Senna obtusifolia seeds were obtained in November, 2016 raining season from the premises of Federal College of Education (Technical) Bichi. The seeds were scarified in hot water for three minutes before planting (Abdulazeez, 2016). Four seeds were planted per hole and thinned to one stand per hole two weeks after sowing, seeds were planted by hand in 1cm deep furrows for all the treatments. There were four ridges for each treatment, a ridge was 300cm long and 50cm apart, all treatments (sub-plots) were replicated three times in a randomized complete block design (RCBD). Weeds were controlled by hand hoeing twice, first at three weeks after emergence with second weeding at four weeks after the first weeding. First manual fertilizer application (3g/plant) was four weeks after emergence with second application at four weeks after the first application as top dressing.

Fig. 4. Job opportunity; Phase (18 – 49 days after planting) to harvest senna obtusifolia leaves for human delicacy (Tafasa food).

Fig. 5. Job opportunity; Phase (84 days after planting) to harvest senna obtusifolia plant for livestock feed (hay).

Fig. 6. Job opportunity; Senna obtusifolia economic plant at maturity. 158 days after planting to harvest seeds for export and raw materials for industries.

Fig. 7. Number of pods yield (32) of senna obtusifolia plant from narrow intra-row spacing of 10cm between plants.

Fig. 8. Number of pods yield (65) of senna obtusifolia plant from medium intra-row spacing of 25cm between plants.

Fig. 9. Number of pods yield (221) of senna obtusifolia plant from wide intra-row spacing of 50cm between plants.

Table 1: Over five months biological characteristics observed in senna obtusifolia economic plant indigenous to Bichi, Sudan Savannah, Nigeria, at optimum intra-row spacing of 50 cm between plants.

*Class - legume plant, *stem – herbaceous, sub-shrub, cylindrical with multiple branches; days to seed-emergence- 3 – 4; seeds per plant – 6,188; *seeds per pod- 23-28; *pod length - 12- 18 cm and 2-5mm diameter; pods/plant – 221; root nodule - none; root - primary root 72cm long with multiple secondary roots; above soil dry matter weight per plant – 177.1g ; *seed coat – hard; *seeds colour – dull or lustrous; weight of dry pod - 1.2g; seed weight - 0.025g; pod colour – light brown or mix light brown and black; *prefer soils – loam, loam sand, sand, and clay; days to first flower bud – 62; days to flower - 71; days to first pod - 73; days to harvest for animal feed (hay) - 84; days to harvest for human delicacy - 18-49; plant height - 1.63m; days to plant/seed maturity (for commerce/industry) – 158 days; *growth cycle - annual plant; *self pollinated; *dehiscent, cylindrical sickled - shaped pod; *seeds disperse through wind, water, animal, shoes and machinery. *leaves alternate, pinnately compound in pairs 2, 4 to 6 obovate leaflets;* largest leaflet, 2-3 cm long, 1-1.5 cm wide; leaf pedicel - 1.7cm long; canopy length 184 cm: petals - yellow, 0.6mm long, 0.4mm wide; sepals green, 0.4mm long, 0.3mm wide; style - one; filaments - seven; *fertile stamens, filaments and anthers; pests – pod/seed borer and foliage beetles; economic plant – yes; uses – livestock feed and material well-being of mankind.

Senna obtusifolia biological characteristics with asterisk (*) corroborate the findings of Irwin and Barneby, 1982, Retzinger, 1983, Mackey, et al. 1997, Everest, Thomas and John 2016. Days= days after planting.

2.4 Data collection, Measurement of Plant Traits and Statistical Analysis.

Eight plants from each treatment were randomly selected. The plants were cut off at the ground surface at maturity. Pods and plants maturity had been considered when the pods and plants were hard and changed from green to very brown colour. Plant traits were translated to plant height (PL.HT), number of pod (NOP), number of seeds (NOS), canopy length (CL), dry matter weight (DMW), total seed yield (TSY) and days to maturity (DTM). The plants height were measured, pods and seeds were carefully harvested manually, threshed, counted and weighed. Total grain yield and above soil dry matter masses per plant were determined. Eight plants within each treatment were randomly measured to obtain average biological trait measurements per treatment. Data were subjected to analysis of variance using IBM SPSS Statistics 20.0 version and treatment means were separated using Duncan Multiple Range Test.

III. Results and Discussion

3.1 Plant height: Statistical analysis for plant height (Table 2) showed significant differences among the intra-rows plant spacing. The plants spaced in intra-row 10cm apart produced tallest plants (184cm) followed by intra-row 25cm and intra-row 50cm distances between plants giving 178cm and 163cm respectively. The recent results confirm the findings of Ron (2015) who reported that plants that are close to each other compete for nutrients and available sunlight for survival by growing tall.

3.2 Number of pods per plant: Data presented in Table 2 show that number of pods per plant in senna obtusifolia plant was highest (221) when the plant was sown at wide intra-row spacing of 50cm apart, followed by medium intra-row spacing of 25cm (65), the narrow intra-row spacing of 10cm exhibited minimum number of pods per plant (32). It was apparent that at narrow intra-row spacing number of pods decreased, which may be attributed to severe competition between vegetative and root organs of the plants. In the severe competition, the plants could not obtain optimal sunlight and nutrients for optimal growth and yield and consequently can be followed by decreasing number of pods per plant.

3.3 Number of seeds yield in wide intra-row and narrow intra-rows spacing: Favourable number of seeds yield per plant was achieved in experiment assigned wide intra –row spacing. The highest number of seeds per plant (6,188) was obtained from wide intra-row spacing of 50cm, followed by medium intra-row spacing of 25cm and narrow intra-row spacing of 10cm distances between plants, giving (1,820) and (896) seeds per plant respectively. The results corroborate the findings of Kwon et al, (1992) who reported that optimal plant spacing produced high yield per plant (Table 2).

3.4 Total seed yield: The intra-row spacing significantly influenced total seed yield. In this experiment, total seed yield increased by increasing in intra-row spacing. The highest total seed yield was obtained 5.63 tons ha^{-1} at wide intra-row spacing (50cm), followed by 4.0 tons $ha\text{-}^{1}$ at narrow intra-row spacing (10cm) while medium intra-row spacing (25cm) recorded the lowest total seed yield 3.25 tons $ha\text{-}^{1}$ (Table 2, fig. 10). These results agree with previous findings of Kwon et al, (1992), who concluded that least optimal spacing gives low yield per hectare, while the optimal spacing gives high yield per hectare.

3.5 Canopy length: Canopy length differed according to intra-row spacing. The longest canopy length (184cm) was observed from wide intra-row spacing of 50cm, while narrow intra-row spacing with 10cm recorded the least canopy length (68cm), the medium intra-row spacing of 25cm had intermediate canopy length (94cm), (Table 2). The longest canopy length observed from wide intra-row spacing of 50cm between plants could be due to readily obtainable sunlight and nutrients for development of the canopy.

3.6 Days to maturity: According to Table 2, days to maturity was significantly varied among the three intra-rows spacing (treatments). However, days to maturity in wide intra-row spacing with 50cm had the shortest days (158), while the narrow intra-row spacing with 10cm had the longest days (176) to maturity followed by medium intra-row spacing with 25cm (167). In this experiment, days to maturity was highly environmental dependent and this might be expected, since narrow intra-row spacing fosters more optimal micro-climates for prolonging the life span of the plants. The findings are supported by Steckel and Sprague (2004) who reported attributes of narrow spacing to including early canopy closure and more optimal micro-climates.

3.7 Dry matter weight per plant: Results in Table 2 showed that intra-row spacing had significantly ($p<0.05$) effect on dry matter weight per plant. The highest (177.1g) and the lowest (49.4g) dry matter weight per plant were related to the intra-row spacing of 50cm and 10cm respectively, while medium intra-row spacing of 25cm had intermediate dry matter weight per plant (75.6g). The considerable and significant superiority in dry matter weight per plant (177.1g) of wide intra-row spacing of 50cm over the others, may be due to negligible effect of inter planting competition for light, space, water, nutrients and other yield-limiting environmental factors between the plants, hence multiple leaves, branches and highest dry matter weight per plant.

Table 2. Effect of three intra-rows spacing (50cm, 25cm and 10cm) and constant inter-row spacing (50 cm) on means of plant height, number of pod per plant, number of seed per plant, total seed yield tons per hectare, canopy length, days to maturity and dry matter weight per plant of senna obtusifolia plant in 2017 cropping season.

	Intra-rows spacing (cm)		
Plant characters	50	25	10
Plant height/plant (cm)	163^{a}	178^{b}	184^{c}
Number of pod/plant	221^{a}	65^{b}	32^{c}
Number of seeds/plant	$6,188^{a}$	$1,820^{b}$	896^{c}
Total seeds yield (tons ha^{-1})	5.63^{a}	3.25^{c}	4.0^{b}
Canopy length/plant (cm)	184^{a}	94^{b}	68^{c}
Days to maturity	158^{a}	167^{b}	176^{c}
Dry matter weight/plant (g)	177.1^{a}	75.6^{b}	49.4^{c}

Different letters within a row indicate significant difference according to Duncan Multiple Range Test ($p<0.05$).

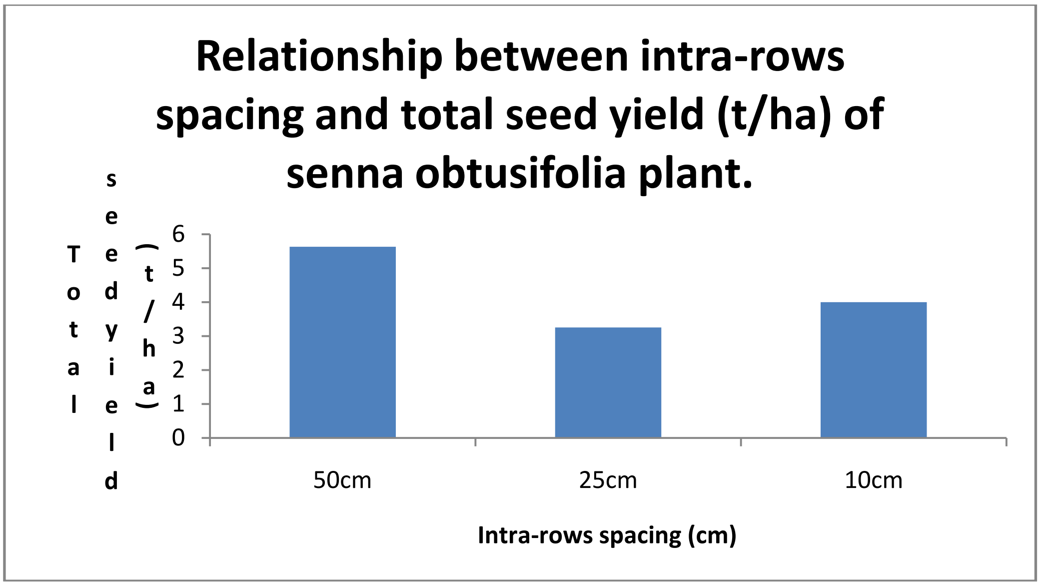

Fig. 10. Relationship between the three intra-rows spacing and total seed yield (tons per hectare) of senna obtusifolia plant. .

3.8 Hypothesis

3.8.1 Hio: hypothesis is tested at 0.05 level of significant. There is no significant ($p>0.05$) difference in senna obtisifolia means total seed yields (tons per hectare) of the three intra-rows spacing.

3.8.2 Re-hypothesis

3.8.3 The non hypothesis (Hio) is rejected. There is significant ($p<0.05$) difference in senna obtisifolia means total seed yields (tons per hectare) of the three intra-rows spacing (Table 2, fig. 10).

IV. Conclusion and Recommendation

Senna obtusifolia is not a notorious weed and should not be endangered with herbicides; the environmental pollutants, costly and notorious climate change agents. Rather Senna obtusifolia is an economic plant which has wide range of local and international uses in food, feed, medicine, gum, paper and textile industries. It is a source of foreign exchange and employment in agriculture, from senna obtusifolia seeds collection, seeds treatment, land preparation, planting, plant management, harvesting, and seed value change, transportation to industrial processing of the senna obtusifolia plant for human and animal uses. Senna obtusifolia seeds are renewable, freely available in tropical countries and the plant is human friendly. The present experiment revealed that intra-rows spacing affected growth, yield and yield components of senna obtusifolia. It was apparent that at narrow intra-row spacing of 10cm, number of pods per plant and dry matter weight per plant decreased, which was attributed to severe competitions between vegetative and root organs and consequently followed by decreasing number of seed per plant. It is concluded that intra-row spacing could be practiced to increase growth, yield and yield components of senna obtusifolia. Since tropical countries of the world are the important production areas for senna obtusifolia, it is recommended that agriculturists and farmers' adopt intra-row spacing of 50cm in order to increase production of senna obtusifolia plant to enhance livestock feed production, further research, profitability and economic diversification in tropical countries of the world, Nigeria in particular.

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