

Influence of Planting Methods and Density on Performance of Chia (*Salvia hispanica*) and its Suitability as an Oilseed Plant

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Abstract

A 2-year field experiment was conducted in 2012 and 2013 at the research fields of CSIR-Crops Research Institute to determine the best agronomic practices for the field establishment and cultivation of Chia (*Salvia hispanica*) and determine insect pests and diseases associated with the plant. The study also determined the nutritional composition of the plant under Ghanaian environment. A split-plot field trial with 2 planting methods (direct planting with seed; planting from seedling) as main plot and 3 planting density (10,000 plants/ha; 20,000 plantst/ha; 40,000 plantst/ha) as subplot were used for the agronomic evaluation of the plant. A sweep net was used to sweep diagonally across the field under two separate regimes to collect insects on the crop for the entomological investigations. Major insects collected were coreid bugs, *lagria* sp., *Zonocerus variegatus* and *Diopsis thoracica*. The method used for the pathological investigations were the moist blotter test and culture of pathogens on Potato Dextrose Agar. The results of the study in both years show high biomass and seed yield of chia when the crop was planted directly in the field. Narrow-row spacing of 0.5m x 0.5m consistently produced the highest biomass and seed yield in both years of the study. The results indicated that interaction between planting method and planting density positively influenced most of the growth and yield parameters of Chia plants. Nutritional profile analysis from the Chia seeds shows medium to high proximate and mineral composition. Disease evaluation revealed evidence of *Fusarium wilt* infection on *Salvia hispanica* in the field. The study recommends the adoption of direct planting method and narrow-row spacing (0.5m x 0.5m) (SP3) as the best option for the production of Chia plants in Ghana.

Keywords: Chia (*Salvia hispanica* L.), planting method and density, pathology, entomology

1. Introduction

Chia (*Salvia hispanica* L.) is a mint plant in the *Lamiceae* family, and is indigenous to Mexico and parts of South America. It is an annual herbaceous plant considered as a Novel Food. Chia does best in sandy, well-drained soils with a low nutrient content, moderate salinity and soil pH of 6 to 8.5 (Landon, 1991). Rainfall conditions are highly variable between the different cultivars, ranging from 300 to 1,000 mm during growing season. Optimal for Chia growth is a well distributed rainfall

during early growth and development and dry conditions during seed maturation and harvesting (Challinor, Wheeler, Craufurd, & Slingo, 2005).

The cultivation of Chia (*Salvia hispanica*) is gaining popularity in Africa because it is considered as a good nutritional and healthy food (Ayerza & Coates, 2000). The plant has a high percentage of fibre, protein, Omega-3, Omega-6 and essential fatty acids (Ayerza & Coates, 1999). The Chia seed has become a popular health food due to its powerful nutrient composition. It is grown for human consumption especially due to its richness in Omega-3 fatty acids, fiber and is a great source of antioxidants and amino acids - particularly lysine. The seeds contain about 20% protein, 35% oil and an impressive 25% dietary fiber and also offer a range of vitamins and minerals, including calcium, phosphorus, magnesium and zinc. Because of its nutritional value and stability, chia is already being added to a range of foods (Ayerza & Coates, 2002). Feeding Chia to chickens enriches their meat with omega-3 and to cattle it enriches their milk with omega-3 (Ayerza and Coates, 2002). Chia can also be added to commercially prepared infant formulas, baby foods, baked goods, nutrition bars, yogurt and other foods.

For a new crop being introduced, different aspects of plant population and spatial arrangement need to be understood. Several workers have reported higher yields in narrow-row compared to wide-row systems in many crops (Ottman & Welch, 1989). Research has shown that yield increases in these systems are closely related to increased light interception that occurs in narrow versus wide-row spacing (Dalley, Kells, & Renner, 2004). McGriff, Baldwin, and Hudgins (1999) consistently found that tomato spotted wilt virus was reduced when planted in narrow-rows. Brown *et al.* (2005) noted that decreasing row spacing increases the plant population density and this dilutes the thrips vector such that there is a lower probability of individual plant infestation. Schilling and Gibbons (2002) reported that wide spacing giving lower plant densities open up the crop to infestation by aphids which prefer light and airy conditions. Lee *et al.*, (1994) also reports that complete crop cover over the soil inhibits weed seed germination and reduces the need to control weeds. Early canopy closure likewise smothers weeds and reduces weed/crop competition, especially for soil nutrients and soil water (Thelen, 2006). Increases in yield under such narrow-row spacing have been attributed to improved weed control as observed in sole peanut and soybean based systems (Dubey, 1998).

The study seeks to assess the performance of the plant in Ghana. This would provide useful information on cultivation of the plant. The trial consists of agronomic studies, pests and disease assessment and nutritional composition analysis of the seeds. The specific objectives of the trial are to determine the best agronomic practices for the field establishment and cultivation of the plant; conduct insect pest and disease prevalence on the crop and determine the nutritional composition of the plant under Ghanaian environment.

2. Materials and Methods

2.1 Study Area

The study was conducted during the major raining season of 2012 and 2013 on the research fields of CSIR-Crops Research Institute, Fumesua, in the semi-deciduous forest zone in Kumasi. The site lies between latitude 06° 43' N and longitude 01° 36' W of the Greenwich meridian. The soils, ferric Acrisol belong to the Asuansi series with about 5 cm thick top layer of dark grey gritty sandy loam (FAO, 1990). The soil pH was slightly acidic and ranges from 5-7. The site is characterized by a bimodal rainfall pattern. The major rainy season starts from March - July and the minor season starts from September - November. There is a short dry period in August. The mean annual precipitation is about 1,500 mm while mean monthly temperatures range from 24 - 28 °C.

2.2 Experimental Design and Field Demarcation

The experiment was conducted using a split-plot design with three replications. The main plot treatment was planting method (direct planting and transplanting) and the sub-plot treatment was planting density (1m x 1m (SP1); 1m x 0.5m (SP2) and 0.5m x 0.5m (SP3)) thus, 10,000 plants/ha; 20,000 plants/ha and 40,000 plants/ha respectively. The direct seeding in the field and the nursery were done the same day. The seeds were nursed in the field to facilitate easier hardening and adaptation to the field. Seeds were nursed on raised beds in the field and in drills. The seeds were spread in the drills and covered lightly to enhance germination. Irrigation was carried out regularly to avoid water stress. A field measuring 66m x 43.5m for 3 replicates (21m x 13.5m per replicate) was slashed, ploughed and harrowed to a fine tilt for the experiment. Eighteen plots, each measuring 6m x 6m was laid out for the experiment. The seedlings were transplanted at 25 days after emergence to the field.

2.3 Soil Sampling

A soil auger was used to take soil samples at random on each experimental plot at depths of 0 to 20 and 20 to 40 cm before planting in accordance to (Anderson & Ingram, 1998). A sizeable quantity of composite soil samples were air-dried and sieved through a 2 mm mesh and subjected to physical and chemical analysis. The soil was analysed for pH, organic carbon, total nitrogen, potassium, phosphorus, exchangeable K, Na and Ca contents, dry bulk density and particle analysis.

2.4 Data Collection

Data were collected bi-weekly on growth (plant height, stem girth, canopy spread, internodes length and number of leaves) of the plant. The number of days to 50% flowering was also recorded. Fresh and dry biomasses were taken at physiological maturity (66 days after planting) and seed yield at harvest (92 days after planting).

2.5 Pest and Disease Evaluation

Insects associated with the crop were collected and categorized using sweep net. The net was swept diagonally across the field to collect insects on the crop. Counts of insects and their damage assessment were recorded. Using the two middle rows, all plants on each plot were examined. Any insect observed was recorded as well as plants with signs of damage.

Plants showing symptoms of defoliation and wilting were uprooted and used for the pathological assessment. The parts of the plants used were root, stem, leaves and soil on roots. The methods used for identification were the moist blotter test and culture of pathogens on Potato Dextrose Agar.

- i. Blotter method: Diseased samples of the Chia plant (leaves and roots) were excised from lesion margins and surface sterilized by immersion in 4% sodium hypochlorite (NaOCl) for 5 minutes. The pieces were then rinsed three times with distilled water, dried with sterile filter paper and plated on three water-soaked filter papers in 9-cm diameter Petri dishes, five pieces per dish. The plates were incubated under alternating cycles of 12 hour darkness and 12 hour near ultra violet (NUV) light and examined on the fourth and fifth days. On day four, the samples were examined individually for the growth of fungal organisms under the stereoscopic microscope. The identification of the fungi was based on habit and morphological characteristics of the fruiting bodies. Slides of the fruiting structures were prepared, and spores/conidia of fungal organisms observed under the compound microscope. The examination was repeated on the fifth day.
- ii. Agar plate method: Potato Dextrose Agar (PDA) was prepared from readymade powder (Difco Laboratories, Detroit, MI). Thirty-nine grams of the powder was dissolved in 1 litre of distilled water. The agar medium was sterilized in pyrex bottles at 121⁰C at

15lbs/pressure per sq. inch (p.s.i.) in an autoclave for 20 minutes. After the agar medium had cooled down to around 50°C, an antibiotic (0.3g Streptomycin sulphate) was added to prevent growth of bacteria. The medium was then poured into sterile Petri dishes in a laminar flow cabinet. The dishes were allowed to solidify completely before plating with the diseased samples. On the fourth and fifth days, fungi growing out from the plated samples were examined and identified based on colony characters and morphology of sporulating structures under the stereoscopic and compound microscopes.

2.6 Seed Nutrient Analysis

The proximate nutrient analyses were carried out by the methods of Association of Official Analytical Chemist [AOAC] (2000) and the standard Association of Official Analytical Chemist [AOAC] (1990) at the laboratory of CSIR-Food Research Institute. The mineral composition was analysed using Permanganate Titrations, Molybdenum Blue Calorimetric and Atomic Absorption Spectrophotometric methods.

2.7 Data Analysis

Data collected were subjected to analysis of variance using Genstat statistical software (9th edition) and when ANOVA was significant means were separated using the SED values at 5% level of significance.

3. Results and Discussion

3.1 Initial Soil Composition

The soil of the study area was initially characterized in order to assess its fertility status before the imposition of the treatments. The results of the initial physico - chemical analyses of the Asuansi soil series (Ferric Acrisol) are presented in Table 1. The soil pH was moderately acidic at both depths and years. This was by virtue of the medium exchangeable calcium content of the soil. Adjei-Gyapong and Asiamah (2002) reported pH of 6.4 on top soils of Asuansi soil series.

Table 1. Physical and chemical properties of soils at horizons 0-30 and 30-60 cm for 2012 and 2013

	Soil depth	pH 1:1 H ₂ O	% Carbon	% Total Nitrogen	% organic matter	Exchangeable Cations				% base Saturation	Available – brays		Texture
						Ca	Mg	K	Na		P Ppm	K Ppm	
At planting	0 – 30	5.76	2.56	0.25	4.41	4.54	0.52	0.29	0.07	91.55	110.81	118.37	Sandy loam
	30 – 60	5.91	2.04	0.18	3.52	6.94	1.87	0.41	0.11	97.39	135.52	164.38	Sandy loam
At harvest	0 – 30	5.98	2.43	0.22	4.19	7.21	1.07	0.26	0.07	98.29	91.70	101.97	Sandy loam
	30 – 60	5.83	1.97	0.18	3.40	6.14	0.80	0.21	0.06	96.01	61.39	82.17	Sandy loam

Soil organic carbon and total nitrogen contents were low and the levels of available phosphorus ranged from medium to high at both depths. Exchangeable K, Na and Ca values were below the critical values of 0.6, 1.0 and 10 cmol/kg respectively (Landon, 1991). The low soil organic carbon and total N contents were the result of high temperatures resulting in rapid organic carbon decomposition in combination with a generally low input of organic material. Organic matter is closely associated with the nutrient status of soil because it contributes much to the soil CEC

(Magdoff & Bartlett, 1985). It is also an important source of inorganic nutrients for production in natural and managed ecosystems (Solomon, Fritzsche, Lehmann, Tekalign, & Zech, 2002). The low CEC recorded was due to the low organic carbon content of the soil. The soil property of the study site is generally attributed mainly to the excessive leaching of the soils caused by high rainfall prevalent in the humid rainforest in Ghana and constant plant nutrient uptake by plants with no adequate replenishment.

3.2 Growth

The results of plant height, canopy spread and number of branches are presented in Table 2. Planting method significantly ($P < 0.05$) influenced plant height, canopy spread and number of branches in both years of the study. Direct planting consistently recorded higher plant height, canopy spread and number of branches in both years. This observation might be due to the shocks received and the period needed for the roots of the transplants to get established in the field. This phenomenon results in temporal water deficit and poor growth (Nitzsche, Berkowitz, & Rabin, 1991). Differences in canopy spread could be attributed to environmental factors such as amount of soil moisture and temperature (Nigam, 1992), as well as soil and disease factors affecting seedling emergence and survival. The poor canopy spread on transplanting plots may be due to very high or low temperatures and drought which affects plant establishment (Cox, 1979; Wood, 1968), suggesting direct seeding as the best option.

Table 2. Plant height, canopy spread and number of branches as affected by planting method and spacing in 2012 and 2013

Treatment	2012			2013		
	Plant Height (cm)	Canopy Spread (cm)	Number of Branches	Plant Height (cm)	Canopy Spread (cm)	Number of Branches
Planting Method						
Direct planting	101.1	61.8	21.2	92.9	79.4	26.8
Transplanting	87.0	60.8	18.3	75.9	70.0	19.2
SED	2.3	0.6	0.40	3.93	3.66	3.70
Planting Density						
SPI (1m X 1m)	91.9	61.9	17.8	76.8	76.8	22.8
SP2 (1m X 0.5m)	92.9	61.2	19.0	84.3	74.2	23.8
SP3 (0.5m X 0.5m)	97.2	60.6	22.5	92.1	73.1	22.4
SED	5.7	3.7	0.99	3.11	3.15	3.22
CV (%)	10.5	10.4	8.7	6.4	7.3	24.20

Planting density significantly ($P < 0.05$) influenced number of branches and plant height in 2012 and 2013 respectively. However, there were no significant differences ($P > 0.05$) in canopy spread for both years. SP3 (0.5m X 0.5m) consistently produced the highest plant height, canopy spread and number of branches for both years.

The results obtained for number of branches under different planting densities agrees with the findings of Andrade, Calvino, Cirilo, and Barbieri (2002) who reported of profuse branching in narrow-row cropping compared to wide-row spacing. The results contradict the findings of Farnham (2001) and Porter *et al.* (1997) who reported of intense competition for light by closely spaced crop compared to widely spaced crop and the subsequent rapid depletion of growth resources by closely spaced crop resulting in reduction in growth rate due to depletion of soil nutrients and adverse effects of intra-specific plant competition among narrow-row crops.

Planting method significantly ($P < 0.05$) influenced internodes length but did not significantly influence stem girth (Table 3). Direct planting produced the highest number of leaves (293 and 320) for 2012 and 2013 respectively which was significantly different ($P < 0.05$) from transplanting in 2013 only. SP3 (0.5m X 0.5m) produced the highest number of leaves per plant in both years and this was significantly different from SP1 (1m X 1m) and SP2 (1m X 0.5m) in 2012 only.

The number of leaves produced by plants is influenced by both genetic and environmental factors. The amount of leaves produced is of agronomic importance to the plant as it forms the canopy of the plant. The results of this study confirm the finding of Brown *et al.* (2003) who observed that closed canopy intercepts more solar radiation, reduces loss of nutrients through soil erosion and prevents weed seeds from germinating resulting in high production of leaves. Tillman, Gorbet, Culbreath, and Todd (2006) and Brown *et al.* (2003) also found out that narrow-row treatments resulted in completely closed canopies, which is found to be effective in controlling weed growth resulting in the production of high number of leaves.

Table 3. Stem girth, internode distance and number of branches as affected by planting method and spacing in 2012 and 2013

Treatment	2012			2013		
	Stem girth	Internode Distance	Number of Leaves	Stem girth	Internode Distance	Number of Leaves
Planting Method						
Direct planting	1.63	7.56	293.0	1.86	5.36	320.0
Transplanting	1.19	5.06	276.0	1.77	9.05	270.0
SED	0.24	0.27	31.6	0.14	0.19	45.6
Planting Density						
SPI (1m X 1m)	1.30	5.66	274.0	1.83	6.27	292.0
SP2 (1m X 0.5m)	1.65	6.37	269.0	1.84	7.66	291.0
SP3 (0.5m X 0.5m)	1.28	6.90	312.0	1.77	7.67	302.0
SED	0.26	0.45	37.3	0.13	0.71	28.1
CV (%)	16.5	11.9	22.7	12.0	17.0	16.5

3.3 Seed and Biomass Yield

Direct planting recorded the highest fresh and dry biomass in both 2012 and 2013 however there was significant differences only in the 2013 season (Table 4). Direct planting recorded a significantly highest fresh and dry biomass (2075 and 296 kg/ha) compared to transplant plots (1758 and 274kg/ha) in 2013. Among the planting density, SP3 recorded the highest fresh and dry biomass in both the 2012 and 2013 cropping season. However, there was significant differences

only in the fresh biomass in the 2013 season with SP3 recording the highest fresh biomass (2119kg/ha) as compared to SP1 which recorded the lowest fresh biomass (1714kg/ha) weight. The differences in fresh and dry biomass among the treatments could be attributed to the ability of some of the treatments to achieve higher photosynthetic rates, thereby accumulating higher amount of biomass. Hauggaard-Nielsen, Ambus, and Jensen (2001) reported that competition among closely spaced crops resulted in increases in biomass even at very high plant densities due to a reduction in weed competition and efficient interception and utilization of solar radiation. A similar situation was observed by Dalley *et al.* (2004) who reported that even where wide-row treatments recorded relatively larger biomass than the narrow-row treatments probably due to lesser competition for growth resources compared to narrow-row treatments, the low biomass recorded by some narrow-row treatments was more than compensated for by the additional plants/m², resulting in significantly large biomass yield compared to wider-row spacing.

Table 4. Fresh and dry biomass and seed yield as affected by planting method and spacing in 2012 and 2013

Treatment	2012			2013			
	Fresh biomass yield Kg/ha	Dry biomass yield Kg/ha	Seed yield Kg/ha	Fresh biomass yield Kg/ha	Dry biomass yield Kg/ha	Seed yield Kg/ha	Seed yield Across Years Kg/ha
Planting Method							
Direct planting	1158.0	240.0	2677.0	2075.0	296.0	2532.0	2605.0
Transplanting	1120.0	216.0	2420.0	1758.0	274.0	2238.0	2329.0
SED	94.7	33.6	511.3	181.1	7.6	190.2	172.5
Planting Density							
SPI (1m X 1m)	1147.0	223.0	1580.0	1714.0	277.0	1927.0	1754.0
SP2 (1m X 0.5m)	1081.0	230.0	2857.0	1886.0	278.0	2438.0	2648.0
SP3 (0.5m X 0.5m)	1189.0	232.0	3208.0	2119.0	300.0	2790.0	2999.0
SED	226.7	41.6	225.1	31.5	678.3	309.1	497.7
CV (%)	34.5	31.6	24.6	20.4	19.2	11.9	24.4

Results of seed yield in both years are also presented in Table 3. Direct planting method consistently produced the highest seed yield for both 2012 and 2013 cropping season. However, there was significant differences ($P < 0.05$) in seed yield only in the 2013 cropping season where direct seeding recorded a seed yield of 2532kg/ha as compared to transplanting which recorded the lowest of 2238kg/ha. Direct planting recorded a significantly higher seed yield (2605kg/ha) across years as compared to transplanting which recorded the lowest (2329kg/ha). The high seed yield produced by direct planting compared with transplanted seed yield might be due to early establishment from the directly planted plot compared with the transplant, which might suffer shock; a similar observation was made by Nitzsche *et al.*, (1991).

Among the plant spacing, SP3 recorded a significantly higher ($P < 0.05$) seed yield (3208 and 2790 kg/ha) in the 2012 and 2013 season respectively while SP1 recorded the lowest seed yield (1580 and 1927 kg/ha). The results is consistent with the findings of Xue, Liang, Ma, Lu, and Ren (2002), and Sharifi, Sedghi, and Gholipouri (2009) who reported that plant population density is

known to effect crop environment, which influence the yield and yield components. The results suggest that maintaining *Salvia hispanica* at optimum population levels would help explore maximum natural resources, such as nutrient, sunlight and soil moisture to ensure satisfactory yield. The seed yield obtained is also comparable to yields obtain (often around 3 t/ha up to 5 t/ha) in a study conducted by European Union (2009). Generally, variations in seed yield were observed both among the planting method and density showing that the trait was subjected to influence by the environment.

3.4 Entomological Investigations

Table 5, below, shows number of insects recorded on the plants. In two cumulative sweeps, a total of 35 insects were collected out of which 18 were identified to be sucking insects. Ten belonged to the coreid bugs well known to attack cowpea belonging to the hymenoptera order. Three *Lagria sp* (foliage beetles) in the order Coleoptera, 3 grasshoppers belonging to the order Orthoptera and one *Diopsis* under Dipteran order were also recorded. It was generally observed, that the population of the sucking insect species was higher signifying an important insect pest of the plant. Direct seeding recorded the highest number of coreid bugs. In Table 6, percentage plant defoliation (some damage attributable to insect) per the two middle rows was 100% on the plants. In terms of dryness of leaves, however, direct seeding with closest spacing (0.5 x 0.5m) recorded the highest percentage (84.36%) plants with dry leaves as compared to those transplanted (53.63%). The drying of the leaves might also suggest disease infection.

Table 5. Mean Number of insects recorded on *Salvia hispanica*

Planting Method	Planting Spacing	Coreid bugs	Lagria sp	<i>Zonocerus variegatus</i>	<i>Diopsis thoracica</i>
Direct planting	0.5m x 0.5m	2	0	0	0
	0.5m x 1.0m	5	0	1	1
	1.0m x 1.0m	5	0	0	0
Transplanting	0.5m x 0.5m	0	0	1	0
	0.5mx 1.0m	1	0	0	1
	1.0m x 1.0m	0	1	0	0

Table 6. Mean and Percentage defoliated (damage plants) of *Salvia hispanica*

Planting Method	Planting Spacing	Total No. of plants	No. of defoliated plants	% defoliated. plants	No. of dry leaves on plants	% dry leaves on plants
Direct planting	0.5m x 0.5m	20	20	100	17	84.36
	0.5m x 1.0m	24	24	100	17	69.51
	1.0m x 1.0m	24	24	100	11	49.59
Transplanting	0.5m x 0.5m	25	25	100	17	53.63
	0.5m x 1.0m	21	21	100	10	49.89
	1.0m x 1.0m	21	21	100	11	55.43

3.5 Pathological Investigations

Plate 1 below show a wilted *Salvia* plant. From the preliminary disease investigation, there was enough evidence of disease infection on *Salvia hispanica* in the field which requires good management strategies. The organisms identified from the moist blotter and agar plate methods

were *Fusarium solani*, *Pallidoroeseum sp.*, *Rhizopus sp.*, *Cladosporium sp.* and the suspected disease is *Fusarium wilt*. This is evidenced by some plants which were found wilted in the field plot.



Plate 1. A wilted plant caused by *Fusarium sp*

3.6 Proximate and Mineral Composition

The mean proximate composition of Chia seeds is presented in Table 7. The nutritional profile obtain from the Chia seeds from this study were within the range obtained for proximate nutritional profile of Chia seeds by the European Commission (1997) and the Australian Government National Measurement Institute [AGNMI] (2009). Slight differences in nutritional composition between the results of this and those reported in the table below could be attributed to genetic variation, season of harvest and the agronomic factors of the sampled varieties as reported by (Onwueme & Charles, 1994). The high level of minerals reported in this study is commensurate with the high soil concentration of this mineral in the soil where the experiments were conducted as shown in the soil data (Table 1). The concentration of minerals in the soil and the age of the plant have also been reported to influence variation of minerals (Fennema, 1988).

The high protein, carbohydrate, calcium, phosphorus, copper and zinc content compared with those reported by European Union (2009) and AGNMI (2009) by virtue of their high nutritional content. This could be utilized in the preparation of protein and carbohydrate- based foods for the prevention of allergic diseases and fibre based foods for activation of intestinal bifidobacteria for good digestion and vitamin synthesis as reported earlier by Rehm and Espig (1991), and Sotozono (1989). This suggests the potential of growing Chia in Ghana.

Table 7. Proximate and Mineral (g/100g) Composition as affected by planting method and spacing in 2012 and 2013

Treatment	Moisture	Ash	Fat	Protein	Carbo- hydrate	Energy	Crud fibre	Free fatty acids	Calcium	Phosphorus	Zinc	Copper	Manganese
Direct planting	9.1	5.50	21.6	25.51	20.39	378.0	17.9	0.4	589.3	230.1	25.29	11.17	11.8
Transplanting	8.9	7.19	22.9	25.61	16.71	375.4	17.09	0.3	1166.6	211.6	22.14	11.30	10.08
European Commission, 2009	8	-	25	19	40	436	25	-	665.40	816.95	4.85	2.16	-
AGNMI, 2009	-	5.05	31.6	19.9	39.85	-	36.5	-	570	735	-	-	-

Source: Australian Government National Measurement Institute [AGNMI], 2009

4. Conclusion and Recommendation

Planting method and planting density had influence on growth and yield of *Salvia hispanica*. Generally, the study have shown that the higher the planting density the greater the biomass and seed yields. The study has also shown that direct planting at 0.5m x 0.5m planting density produced the highest biomass and seed yield in both years of the study. The study have also demonstrated that a linear relationship existed between growth and yield parameters of Chia plant as treatments with high growth yield was translated into high biomass and seed yield.

The proximate and mineral composition analysis have shown medium to high nutritional profile of Chia seeds from the study compared with the results reported by European Union, (1997; 2009) and AGNMI (2009) indicating the nutritional potential of Chia planted in Ghana. The pests and disease investigation of the study have revealed enough evidence of *Fusarium wilt* infection on *Salvia hispanica* in the field which requires good management strategies to control. Pest and disease control trials on the plant would be needed to determine the appropriate pesticides necessary for the control of the pests and pathogens identified on the crop. Although, the study suggest exploring planting densities higher than 40,000 plants/ha (SP3) to arrive at the optimum planting density of the plant, for now the adoption of direct planting method and narrow-row spacing (SP3) as the best option for the production of Chia plants in Ghana.

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