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Effects of Sett Size and Spacing on the Growth and Yield of Ginger (Zingiber officinale Rosc.) at Areka, Wolaita, Southern Ethiopia

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Abstract
An experiment was conducted to determine the effects of sett size and spacing on the growth and yield of ginger during 2008 cropping season, at Areka, Southern Ethiopia. The experiment consisted of factorial combination of three inter row spacings (20, 30 and 40 cm), three intra-row spacings (5,10 and 15 cm) and three ginger rhizome sett sizes(≤ 3 cm, 3.1 to 6 cm and 6.1 to 9 cm). The design was split-split-plot with three replications. Inter row spacing, intra-row spacing and sett size were assigned to the main plot, sub-plot and sub-sub-plot, respectively. Data on plant growth parameters, yield and yield components were recorded and analyzed. The results showed that in general plants attained higher canopy establishment and reached maximum growth between 120 and 165 days after planting and thereafter declined due to senescence. The interaction effect of inter row spacing by sett size was significant on total biomass$ha^{-1}$and dried rhizome yield ha^{-1}.Inter row spacing had significant ($P < 0.05$) effect on number of tillers $plant^{--1}$, leaf area per plant, leaf area index, rhizome length, rhizome width, rhizome fingers $plant^{--1}$, rhizome fresh weight ha^{-1} and harvest index but non significant effect on date to 50% emergence and 90 % maturity and other growth parameters. Intra-row spacing had significant ($P < 0.05$) effect on number of tillers $plant^{--1}$, plant height, number of leaves per plant, shoot dry weight $plant^{-1}$, leaf area, leaf area index, rhizome fingers and total biomass. Sett size also significantly ($P < 0.05$) affected emergence, maturity, number of tillers $plant^{-1}$, plant height, leaf length & width, shoot dry weight leaf area, leaf area index rhizome fresh weight ha^{-1} and harvest index. All the parameters increased with increased in rhizome sett size. The findings showed that growth, yield and yield components of ginger can be improved by using appropriate sett size. In the study the maximum fresh rhizome yield (41808 kg ha^{-1}) was achieved using sett size 6.1 - 9.0 cm irrespective of the inter and intra-row spacings, which is similar with recommendation from Tepi and it could be recommended for use by ginger producers in the experiment area and its surroundings. Influence of inter row spacing (20 and 30 cm) was significant while that of intra-row spacing was not on fresh rhizome yield. However, higher yield was obtained from 10 and 15 cm inter row spacing. Therefore, it is advisable to use 20x15 cm and/or 30x10cm inter row and intra-row spacings interchangeably. However, further studies should be conducted to see consistency of the results and come up with site specific recommendation.
Keywords: Ginger*;* spacing; sett size; Growth; Yield

1. INTRODUCTION

Ginger (*Zingiber officinale* Rosc.) is an erect, leafy perennial herb; usually cultivated as an annual, hard laterally compressed, with purple flowers and a robust branched rhizomes covered with small scale leaves growing horizontally near the soil surface (Kochhar, 1998; Weiss, 2002). It is a perennial crop usually grown as annual and it exhibits the sigmoidal growth pattern that started from a period of slow growth during establishment which followed by a phase of rapid growth rates and finally, growth rates decline as the canopy senesces.

Ginger is an important tropical horticultural plant, valued all over the world as a spice in culinary preparation and specially in South and East Africa and South East Asia the plant regarded medicinal properties as virtual panacea (Bhagyalakshmi and Singh, 1988; Rout, et al., 1997). Dried ginger is widely used in food preparations. The aroma of ginger is pleasant and spicy and its flavor penetrating, slightly biting due to antiseptic or pungent compounds present in it, which make it indispensable in the manufacture of a number of food products like ginger bread, biscuits, cakes, puddings, soups, ginger ale, curry powders, certain soft drinks like cordials, ginger cocktail, carbonated drinks, bitters, etc. Ginger is also used for the manufacture of ginger oil, oleoresin, essences, tinctures, etc (Pulseglove, 1972; NIIR, 2002).

In Ethiopia, ginger is a popular spice and is used together with other spices, as a food spice in 'Wots'. The fresh and dried ginger has the same use. It is also an ingredient of the mixture from which local alcoholic drinks are prepared and some people use it to flavor their tea (Jansen, 1981; Nigist and Berhanu, 1989). In general, ginger is used internally as a stimulatory carminative and externally as a rubefacient and counter-irritant (Purseglove, 1972). In Ethiopia, South and Southeast, and Southwest Africa, people use it as medicine against colds, teeth ache, stomach, fever, coughs, headache, catarrh, rheumatic pains, neuralgia, etc (Purseglove, 1972; Jansen, 1981).

From the analysis of one kg, Purseglove (1972) obtained that a dried ginger has moisture content of

10%, the rhizomes contain a volatile oil ranged 1-3%, of which the chief component is zingiberene ($C_{15}H_{24}$). Zingerone is the pungent principle, present in the Oleoresin. In other report, Jansen (1981) has reported for a kg of fresh ginger in Ethiopia that contains protein ranged from 24 - 42 g, fat 5-11 g, carbohydrate 207-222 g, fibre 13-19 g, nitrogen 4-6 g, Ca 270-430 mg, P 470 mg, iron 33-283 mg, thiamin 0.3- 0.7 mg, riboflavin 0.1-11mg, niacin 5-7 mg, ascorbic acid 10 – 50 mg and others.

Besides these, the crop has multiple advantages in that it is highly productive per unit area, tolerant to drought and disease, can be stored for long period of time in dried form and can be inter cropped with other crops like beans, maize, taro, coffee, etc. and used for various purpose in different forms (Jansen, 1981).

The principal ginger producing countries are India, Jamaica, Sierra Leone, Nigeria, Southern China, Nepal, Pakistan, Japan, Taiwan, Australia, Mauritius, Malaysia and Indonesia. Of these Jamaica and Sierra Leone, produce superior quality ginger followed by Nigeria. India and China are the two largest producers and major exporters of ginger in the world market. The major importers of ginger are the Middle East countries, USA, and West European countries (NIIR, 2002).

Ginger is known to be introduced to Ethiopia as early as the 13th century and perhaps its cultivation has also been started since then (Jansen, 1981). Ginger requires warm and humid climate and adapted to altitudes from sea level to 1500m with rainfall of 1500mm or more per annum (Leverington, 1983; Purseglove, 1972). However, in Ethiopia, it is often cultivated under sub optimal conditions, for instance at altitudes up to 2000 m, with rainfall often less than 1500 mm per year and at lower temperature. It is mainly grown in the wetter regions of Keffa, Illubabor, Gamo Gofa, Wolaita and Wollega mostly in gardens (Jansen, 1981). A long ago, Large-scale production is reported by Jansen (1981) from around the Illubabor and Wolaita and for the Gumuz people, and it is well known as major cash crop for sale on most markets in Ethiopia. However, nowadays ginger cultivation in Ethiopia is limited mostly in the wetter regions of the South Nations, Nationalities, and People's Regional State (SNNPRS) and in some parts of Western Oromia (Asfaw and Endrias, 2008 unpublished).

Recently, the statistical information from Ministry of Agriculture and Rural development on strategy of ginger development plan indicated that 99% of production was from the SNNPRS and 1% from the Oromia (MoARD, 2003). The small scale commercial production by farmer is practiced in SNNPRS in Wolaita, Kambata-Tambaro and part of Baddawacho (Hadiya Zone) taking the leading position in the region as well as in the country as far as the total production and supply to the central market is concerned (Asfaw and Endrias, 2008 unpublished). During the 2007 production year, about 2,896,372 qt of fresh rhizome ginger was produced from the area of 18249 ha in SNNPRS (SNNPRS Bureau of Agriculture and Rural Development, 2007, unpublished report). The standard of living of the farmers cultivating ginger in the region is by far better than from those farmers whose livelihood is based on any other crop. The farmers named the crop as **"The cash in bank"** due to its economic importance and potential in crop diversification and source of income.

Despite its importance and contribution to the livelihoods of small land holders and to the economy of the country, almost no attempt or little attention has been given to improve its production and productivity, and also research on this sector has not been developed due to various constraints (Girma and Digafie, 2004; Asfew and Endrias, 2008 unpublished).

The productivity of crops in general and ginger in particular in farmers′ field affected by a number of factors such as soil fertility, size of planting material, variety, weed, spacing, population density, etc. Plant population plays an important role in contributing to good growth and high yield; because, the dense plant population will not create opportunity for plants to have a proper light for photosynthesis and may lead to high level of disease incidences. On the other hand, very small population will also reduce the expected yield per unit area (Pookpakedi and Patradilok, 1993). Purseglove et al. (1981) reported that inter and intra rows spacing is one of the major factors that influence the growth and development of the ginger and /or any other crop. In addition, optimum sett size especially, in rhizome crops such as ginger and turmeric is critical factor that can affect the growth and yield of the crops because in such plants the seed sett rhizome it self is the commercial product (Grima and Digafie, 2004).

Kochhar (1998) reported that ginger is commercially propagated by portion of rhizome size 2.5 cm - 5 cm long with at least one viable bud. Weiss (2002) also reported that in general, planting material and spacing is local specific and the sett size can vary 3 cm to 6 cm long or about 30 g in weight, inter and intra row spacings 20 - 30 cm and 15 - 20 cm, respectively. Grima and Digafie (2004) showed that sett size > 9 cm to give higher yield with using 15 by 30 cm inter and intra-row spacing and using sett with > 12 cm as was not economical. However, row spacing is also governed by harvesting machineries used. similarly, Purseglove (1972) indicated that sett size to be used 2.5 cm - 5 cm long with more than 17 qt ha^{-1} seeding rate and spacing 23 - 30 cm x 15 - 23 cm; NIIR (2000), sett with 3 - 5 cm length, weighing 20 –30g and having at least one sound bud.

Ravindran and Bacu (2005) reported that the optimum plant density is not stable but changes. The quantity should be adjusted to local conditions and be determined according to type of cultivars and other conditions. It was reported that the maximum recommended rate of plant population per hectare depending on locations to be 289000 (23 cm x 15 cm) in India (Purseglove 1972), and in Jamaica and Queensland 266000 (25 cm x 15 cm) (Jansen, 1981; Pruthi, 1998). In addition, a preliminary study was conducted on the effect of plant population density (inter and intra rows) of ginger on rhizome yield at Tapi, western Ethiopia. From the study, the recommendation of 222,000 plants per hectare (15 cm x 30 cm spacing) (Grima and Digafie, 2004) was given to all areas and locations without considering type of planting material and different environmental conditions. Farmers are also reluctant to use this spacing complaining that it is wider (personal communication). Thus it is of practical importance to determine inter and intra-row spacing for optimum yield of the crop for different climatic and soil conditions. As a result, this study has been carried out with the objective:

- To determine the effect of inter and intra-row spacings and sett size on ginger growth, yield and yield related components.

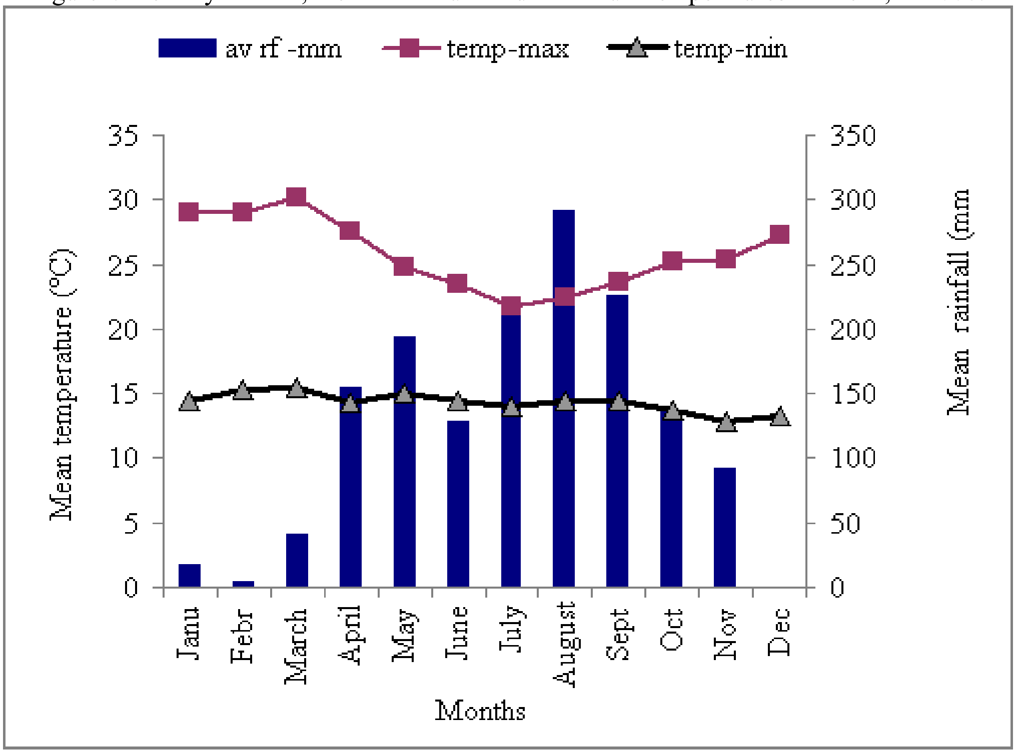
2. MATERIALS AND METHODS

2.1. Description of the study area

The experiment was conducted at Areka vegetable & fruit seeds multiplication site, Boloso Sore woreda, SNNPRS, during the 2008 cropping season. Areka is located at 419 km South of Addis Ababa, 07° 04' N latitude and 37° 47' E longitude, and has an elevation of 1750 m above sea level (asl). The average annual rainfall of the area for the last ten years (1998 - 2007) was 1483.83 mm. The mean peak rainy months are April, July, August and September. The average annual minimum and maximum temperatures are 14.58 °C and 25.8 °C, respectively (AARC, 2009, unpublished). The experimental soil was well drained, stone free, with textural class of silt loam, and has a pH of 5.3.

The actual amount of rainfall received from May to November 2008, during the experiment period, was 1216.60 mm, and the current cropping year annual rainfall was 1504.00 mm (Figure 1). The daily mean minimum and maximum average temperatures for 2008 were 13.22 °C and 23.54 **°C,** respectively (Appendix 1A, B & C).

Figure1. Monthly rainfall, mean minimum and maximum temperatures at Areka, in 2008.



2.2. Treatments and experimental design

The treatments consisted of three levels of inter row spacings (20, 30, & 40cm), three levels of intra-row spacings (5cm, 10cm, & 15cm), and three levels of planting materials (sett size) with sizes ≤ 3.00 cm, 3.1-6.00 cm, and 6.1- 9.00 cm long with an average weight of 12.13 g, 27.4 g, and 34.13 g, respectively.

The experiment was laid out in a split-split plot design with three replications, where inter row spacing, intra-row spacing and planting material (sett size) were arranged as a main plot, sub plot, and sub- sub plot factors, respectively. Plant density in the experiment was differed by varying inter and intra-row spacings as treatment factors. There were 27 plots per replication, that each plot consisted of seven rows of 1.35 m length with different number of plants per plot according to different spacings used, and the net plot sizes were 1.89 m^2, 2.83 m^2, and 3.78 m^2 for 20, 30, and 40 cm inter row spacing, respectively. Blocks and plots separated one meter and 0.3 m apart, respectively. And also the main plots with in replication were separated by 60cm from each others.

2.3. Experimental procedures

The seed rhizome (sett size) was one year old having at least two active buds. Ginger seed used in the experiment was from the variety locally called Volvo, which was collected from Chema-Hembecho kebele. The experimental land was well prepared manually and depth of planting was 5-10 cm. A shallow cultivation was carried out every 15 days after planting (DAP). Moreover, weeds were controlled by hand weeding as often as required.

2.4. Data collection

Data on various growth characters of ginger were collected from samples of four plants in each plot at 45, 120, 165 and 195 days after planting (DAP) to study the growth trends of the plant. The important parameters and detailed procedures of data recordings were as follows.

Date of emergence: - refers to the days of 50 % of the plants per plot were emerged.

Plant height (cm): – refers to mean height per plant that was measured from the four sampled plants per plot starting from the base of the stem (just above ground level) to the tip of the plant last leaf by using meter tape and divided by number of plants.

Number of tillers per hill: – the mean number of shoots (tillers) produced by four sampled plants. Total number of tillers of four sampled plants were counted and divided by the number of plants to get mean number of shoots per plant.

Leaf number per plant: – refers to mean number of leaves produced per plant. All green leaves produced by the sampled plants were counted and divided by the number of plants to get mean number of leaves per plant.

Leaf length (cm): - refers to the mean leaf length produced per plant. Total length of four plants of five leaves per each plant were measured using meter tape and divided by the number of leaves to get mean leaf length per plant and also divided by number of plants.

Leaf width (cm): – this refers to the mean leaf width (diameter) produced per plant. Total width of four sampled plants of five leaves per each plant was measured and divided by the numbers of leaves.

Shoot dry weight (g/plant): – the above ground parts of four sampled plants were oven dried for 48 hours at 70 °C until constant weight reached and the average weight of them were expressed in gram per plant.

Leaf area (cm^2): - Leaf area (LA) was measured by using leaf length and width of each leaf from each of the sampled plants using a meter tape and multiplied by leaf area adjustment factor (k= 1.426) (Anteneh, et al., 2008).

Leaf area Index (LAI): - it was determined as the ratio of LA to the ground area occupied by the sampled plants**.** LAI = LA/GA. Where: LA is leaf area of a plant (cm^2) and GA is ground area (cm^2).

Days to maturity: - refers to number of days from DAP to when 90 % of the above ground part of the plant senescent and about 60 % dried and when the crop was ready for harvest.

Rhizome thickness (width) (cm): – refers to width (diameter) at the middle of all rhizomes of four plants per plot were measured and divided by number of plants to get its diameter (width) per plant basis.

Rhizome length (cm): – refers to the length of rhizomes were measured from distal end to the proximal end of those four sampled plants and the mean value was taken per plant.

Number of fingers per plant: - the number of rhizome fingers arose from four sampled parent plants were counted and divided by number of sampled plants to get the average fingers per plant.

Total fresh Rhizome yield (kg): – refers to the fresh rhizome yield that was obtained from the middle three harvestable rows of each plot and converted into hectare. It was estimated using the following formula.

$$\textbf{Total fresh yield per hectare (kg)} = \frac{\text{Yield per three rows (kg) x10, 000 (m}^2\text{)}}{\text{Net area of the three rows (m}^2\text{)/ plot}}$$

Dried yield (kg): – about 500 g fresh weight of rhizome was oven dried for 72 h at 70^0C until reaching constant dry weight and the weight determined by using sensitive electronic balance. The fraction of dry weight of sample was computed and equivalent dry weight of total fresh weight was calculated to convert into hectare basis. Fresh weight per net area was multiplied by this fraction:

$$\mathbf{DW_2} = \frac{FW_2 \;\; X \;\; DW_1}{FW_1}$$

Where,
DW1 – dry weight 500 g fresh weight
DW2 – total dry weight ha^{-1}

FW1 – 500g fresh rhizome weight/ net area
FW2 – total fresh rhizome weight ha^{-1}

Harvest index (HI): – was calculated as the ratio of economic yield (rhizome yield) to the biological yield (both above and below ground plant parts). It was expressed as:

$$\mathbf{HI} = \frac{\text{Economic yield}}{\text{Biological yield}} \mathbf{X\ 100}$$

2.5. Data analysis

Mean values were computed for growth parameters such as number of tillers per plant, plant height, number of leaves per plant, leaf length, leaf width, leaf area per plant and leaf area index for data collected at 45, 120, 165 and 195 days after planting (DAP) and sketched in line graph to study trends in growth over time; data of these growth parameters at 195 DAP, which is days to 90% maturity, were subjected to analysis of variance (ANOVA) together with data collected at final harvest. ANOVA was performed using SAS software version 9.0.15716 (SAS, 2002). Mean separation was carried out using Least Significance Difference (LSD) test at 5% level of significance. Correlation analyses were done among the yield, yield components and some growth parameters using Pearson's correlation coefficient.

3. RESULTS AND DISCUSSION

3.1. Plant emergence

Visible crop sprout appeared first at 15 days after planting (DAP) on 18, May 2008, and continued to emerge until 45 DAP. Inter and intra-row spacings had no significant ($P < 0.05$) effect on mean number of days to 50 % emergence (Appendix 2). A similar duration of 29 days was required to achieve 50% emergence under using different inter and intra row spacings (Table 1). The result agreed with the findings of Aynalem (2008) who reported non significant effect of plant population on taro emergence.

Sett size had a highly significant ($P < 0.001$) effect on mean number of days to 50 % plant emergence (Appendix 2). The largest sett size achieved 50 % emergence 27.15 days after planting, which however, was not statistically different from medium sett size (Table 1). The smallest sett size (≤ 3.0 cm or 12.13 g) required longer days to achieve days of 50 % emergence. Days to 50 % emergence thus decreased with increased rhizome sett size. Over the whole range of sett sizes used, increasing sett from ≤ 3 - 3.1-6 cm and ≤ 3 - 6.1-9 cm decreased mean days to 50% emergence by 19.76 and 24.86 %. The results of the study are similar with the findings of Bendell and Daly (1996) in ginger, Onwueme (1978b) in cassava, Onwueme, (1972) in yam and Harris (1978) in potato who reported that the difference in crop emergence depending on plants sett sizes and those large rhizomes and corms emerged faster (earlier) than smaller. The earlier emergence in this experiment might be attributed due to relatively greater amount of remobilizable food reserves; because size affects the amount of reserve food that affects growth rate and vigor of sprouts. While delayed emergence of the small sett sizes may be due to the depth of planting, low amount of food reserves and due to lately produced nature small sett sizes may have also longer dormancy.

All the interactions among treatments (inter row spacing x intra-row spacing, inter row spacing x sett size, intra-row spacing x sett size and inter row spacing x intra-row spacing x sett size) did not significantly influenced mean days to 50 % emergence of plants (Appendix 2).

Table 1. Main effect of means for crop emergence and maturity of ginger as affected by inter row, intra-row spacing and rhizome seed pieces at Areka, 2008

Treatments	50% Emergence (days)	90% Maturity (days)
Inter-row (cm)		
20	29.3	195.37
30	29.41	195.22
40	29.52	195.19
LSD (5%)	NS	NS
CV (a %)	3.85	0.54
Intra-row(cm)		
5	29.56	195.56
13	29.26	195. 3
15	29.41	194.93
LSD (5%)	NS	NS
CV (b %)	2.78	0.5
SET (cm)		
≤ 3.00	33.89a	201.37a
3.1 - 6.00	27.19b	192.26b
6.1 - 9.00	27.15b	192.15b
LSD (5%)	0.52	0.57
CV (c %)	3.17	0.54

Values followed by the same letter (s) with in a column are not significantly different at $P \leq 0.05$.

3.2. Maturity

Neither inter row nor intra-row spacing had significant ($P < 0.05$) effect on days to 90 % maturity of ginger (Appendix 2). The reason for similarity on days of maturity might be associated with it's the same genetic characteristics of the plant. Sett size had a highly significant ($P < 0.001$) effect on mean number of days to maturity (Appendix 2). The largest sett size (6.1-9.00 cm) took significantly lower mean number of days (192.15) to reach maturity, which however, was not statistically different from sett size 3.1- 6.00 cm (Table 1). Sett with ≤ 3.0 cm size took significantly longer mean number of days (201.37) to attain physiological maturity. Days to 90 % maturity thus increased with decrease in sett size of seed rhizome. The magnitude of the increase is nine days over the range of sett sizes used. The possible reason might be associated with early establishment due to access of reserves, vigorous growth that enables plant to have good stand to reach earlier to 90 % days to maturity.

All the interactions among treatments (inter row spacing x intra-row spacing, inter row spacing x sett size, intra-row spacing x sett size and inter row spacing x intra-row spacing x sett size) did not significantly influenced mean days to 90 % maturity of plants (Appendix 2).

3.3. Number of tillers per plant

Maximum number of tillers per plant was achieved at 120 DAP, and declined thereafter (Fig 2A, B, and C); the pattern of tillering is similar with taro that reported the increase of tillers with age increase, with increased spacings as well as sett size (Mulugeta, 2007).

Inter row spacing had a significant ($P < 0.05$) effect on mean number of tillers per plant at 195 DAP growth stages on ginger plant (Appendix 3). At this time, 30 cm inter row spacing gave higher mean number of tiller per plant (1.27), which however, was not statistically different from 40 cm spacing. The 20 cm inter row spacing gave low mean number of tillers per plant at this growth stage (Table 2).

Intra-row spacing highly significant ($P < 0.001$) effect on mean number of tillers per plant at 195 DAP (Appendix 3). Mean number of tillers per plant during the time was significantly higher at both 15 and 10 cm intra-row spacings (1. 33 & 1. 34, respectively) than 5 cm (Table 2).

Sett size had highly significant ($P < 0.05$) effect on mean number of tillers per plant at 195 DAP growth stage (Appendix 3). The sett with 3.1- 6.0 cm and 6.1- 9.0 cm size scored significantly higher (1.3 & 1. 25, respectively) mean number of tillers per plant (Table 2).

Number of tillers on ginger was affected by inter and intra- row spacings as well as sett sizes. Number of tillers increased with increase in inter and intra-row spacings (Table 2). Increasing inter row spacing from 20 to 40 cm increased number of tillers by 11.02 % at 195 DAP. Similarly, increasing intra-row spacing from 5 to 15 cm increased the number of tillers by 25.56 % at 195 DAP. The result of this study is consistent with the work of Whiley (1981) and Ravindran and Bacu (2005) who reported that the numbers of tillers per plant increased when inter rows spacing increased or plant population decreased in ginger. Similarly, Onwueme (1978a, b) on yam and Cassava, and Mulugeta (2007) on taro, reported that increasing plant population per unit area of land resulted in a decrease in yam, cassava and taro suckers' number per plant and vise versa. The possible reason for decrease in tillers number per plant with decrease in inter and intra-row spacings might be due to high competition among plants for growth limiting factors, such as light, soil nutrients and other components.

Number of tillers increased with increase in sett size (Table 2). Over the range of sett size used, increasing sett from ≤ 3 to 6.1-9 cm size increased number of tillers per plant by 14.61 %; at 195 DAP, respectively. The results agree with the work of Whiley (1981) and Ravindran and Bacu (2005) who reported that the number of tillers per plant in ginger increased when sett size increased. All interaction effects of inter and intra-row spacings and sett size were non significant ($P < 0.05$) effect (Appendix 3) on mean number of tillers per plant during 195 DAP periods of data collection.

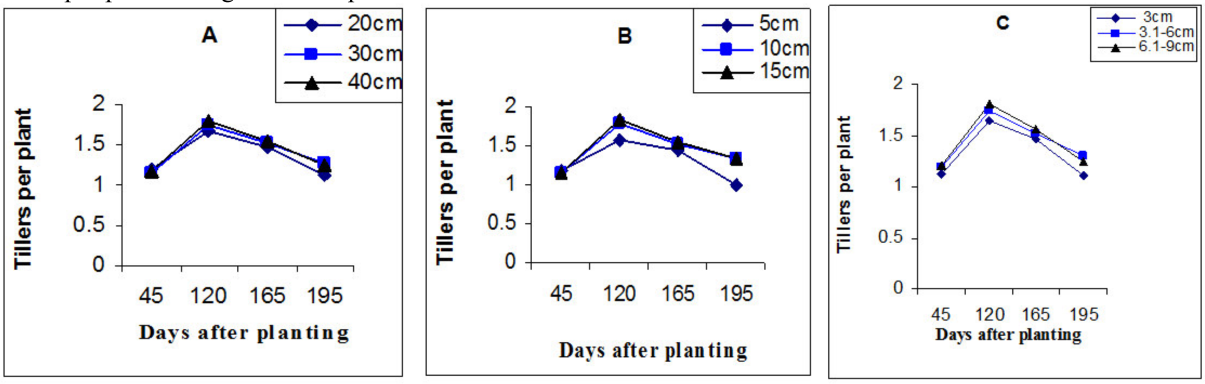


Figure 2. Tillers per plant of ginger at different growth stages as influenced by (A) inter row, (B) intra-row and (C) sett size at Areka, 2008.

20, 30 and 40 cm were inter row spacings; 5, 10 and 15 cm were intra-row spacings and ≤ 3 cm, 3.1- 6 cm and 6.1-9 cm were sett sizes.

3.4. Plant height

Mean plant height varied in relation to growth period. Regardless of inter and intra-row spacings as well as sett size, mean plant height was low at 45 DAP, increase rapidly reaching a maximum at 165 DAP, and declined thereafter (Figure 3A, B, C). Increase in size and height is the life characteristics of most horticultural plants; the slow establishment followed by a phase with rapid rates as the canopy maximum area and declining due to senescence was also genetically programmed nature of the crop. The nature of height in general explained blow in detail with relation to inter and intra-row spacings and sett size.

Inter row spacing had no a significant ($P < 0.05$) effect on mean plant height at 195 DAP (Appendix 3). But intra-row spacing had a significant ($P< 0.05$) effect on mean plant height (Appendix 3). During the maturity period, the 15 cm and 10 cm intra-row spacings scored significantly higher (41. 76 and 42. 72 cm, respectively) mean height than 5cm intra-row spacing (39. 3 cm) (Table 2).

Sett size had significant ($P< 0.05$) and highly significant ($P <0.001$) effect on mean plant height at 195 DAP (Appendix 3). The result showed that, the sett with 6.1- 9.00 cm size scored significantly higher mean plant height (42. 92 cm) than medium sett size (44. 1 cm) and small size (38. 76 cm). The smallest (≤ 3 cm) sett size scored significantly low mean plant height during the entire growth stages (Table 2).

Mean plant height in ginger was affected by intra-row spacings and sett size. Mean plant height increased with increase in intra-row spacing. Generally, the influence of inter row spacing on plant height seem slight and weak during other growth periods. Similarly, increasing intra-row spacing from 5 to 10 cm increased the mean height by 5.8 % at 195 DAP; and increasing from 5 to 15 cm increased by 5.89 %. The result of the study are in line with the findings of Desta (2008), Kanton, et al. (2002) and Hossain et al. (2003) on onion; Elezabeth (2007) on garlic, who reported the decrease of plant height as population densities (inter and intra-rows decreased) increased. The possible reason for the decreased in plant height with decreased row spacings might be due to the increased competition for growth factors from the soil which have resulted in decreased plant growth.

Mean plant height increased with increase in sett size. Over the range of sett sizes used increasing sett size from ≤ 3 to 3.1 - 6.0 cm, ≤ 3 to 6.1 – 9.00 cm and 3.1 - 6.0 to 6.1– 9.00 cm increased mean plant height by 5.69, 9.69, 4.24%, at 195 DAP, respectively (Table 2). The results are similar to the findings of Misra and Nedunchezs (2004) in yam, and Onwueme (1978b) in cassava who found that the sizes of tuber significantly affected the plant height. The possible reason for the maximum plant height might be early establishment of the crop due to availability of more food reserves that help growth for large sett. All interaction effects of inter and intra-row spacings and sett size were non significant ($P < 0.05$) (Appendix 3) on mean plant height during all periods of data collection.

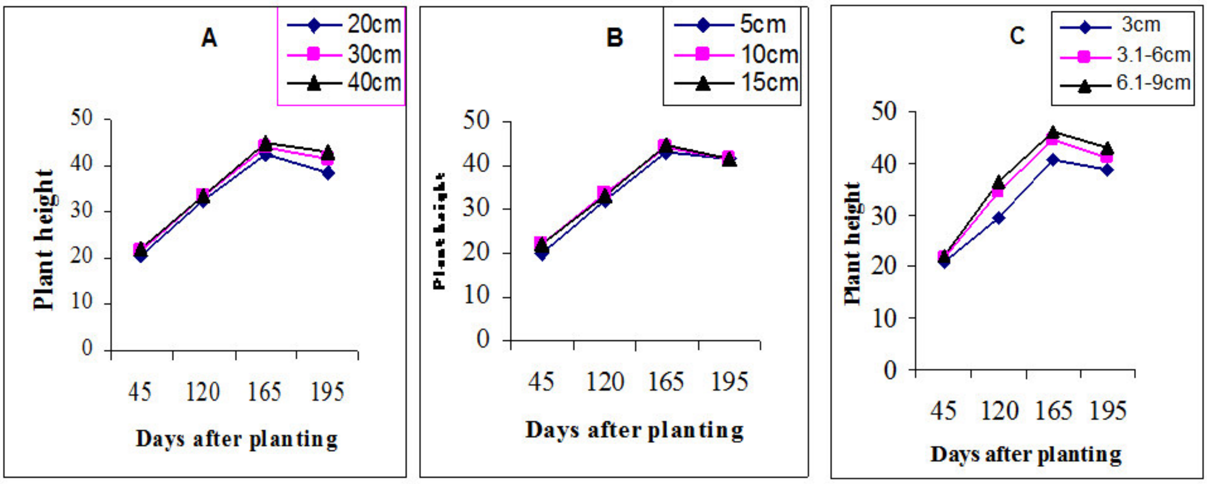


Figure 3. Plant height (cm) of ginger at different growth stages as influenced by (A) inter row, (B) intra-row and (C) sett size at Areka 2008. 20, 30 and 40cm were inter row spacings; 5, 10 and 15cm were intra row spacings and ≤ 3cm, 3.1- 6cm and 6.1-9cm were sett sizes.

3.5. Number of leaves per plant

Mean leaf number per plant varied in relation to growth period (Fig 4A, B and C). Regardless of inter and intra-row spacings as well as sett size, mean leaf number per plant was low at 45 DAP, increased rapidly reaching a maximum at 165 DAP, and declined thereafter. The detail is presented below using growth parameters.

Inter row spacing had no significant ($P < 0.05$) effect on mean number of leaves per plant at 195 DAP (Appendix 3). Intra-row spacing had a highly significant ($P < 0.01$) effect on mean number of leaves per plant at 195 DAP (Appendix 3). The 10 and 15 cm intra row spacing scored significantly higher mean number of leaves per plant at both growth periods than the 5 cm intra row spacing (Table 2).

Inter row spacing had no significant ($P < 0.05$) effect on mean number of leaves per plant at 195 DAP (Appendix 3). Intra-row spacing had a highly significant ($P < 0.01$) effect on mean number of leaves per plant at 195 DAP (Appendix 3). The 10 and 15 cm intra row spacing scored significantly higher mean number of leaves per plant at both growth periods than the 5 cm intra row spacing (Table 2).

Mean number of leaves in ginger is thus affected by intra-row spacing and increased with increasing the inter row spacings (Table 2). The result is in line with the findings of Karye and Yakubu (2005) and Mulugeta (2007) on garlic and taro, respectively. Muhammad (2004) and Hossain, et al. (2003) in onion and garlic, respectively; also reported higher number of leaves at wider intra-row spacing. The possible reason that might be, due to having proper intra row spacing plants grow with less competition for limited available resources compared to more closely spaced plants.

Sett size had significant ($P < 0.05$) effect on mean number of leaves per plant at 195 DAP growth periods (Appendix 3). The largest and medium sett sizes gave significantly higher (14.72 and 14.57, respectively) mean leaf number per plant at 195 DAP than the smaller sett size (≤ 3 cm) (Table 2). Mean leaf number per plant increased with increase in sett size. Generally, plants grown from larger sett size gave significantly higher number of leaves throughout the growing periods. The result of this experiment agreed with the reports of Terefe (2003) on sweet potato and Khalafalla (2001) on potato and Mulugeta (2007) on taro. In these crops, increased seed size resulted in increasing number of leaves. The possible reason for this might be more reserve food accumulation enables them for early ground coverage and greater leaf area index production which may lead to produce more number of leaves per plant.

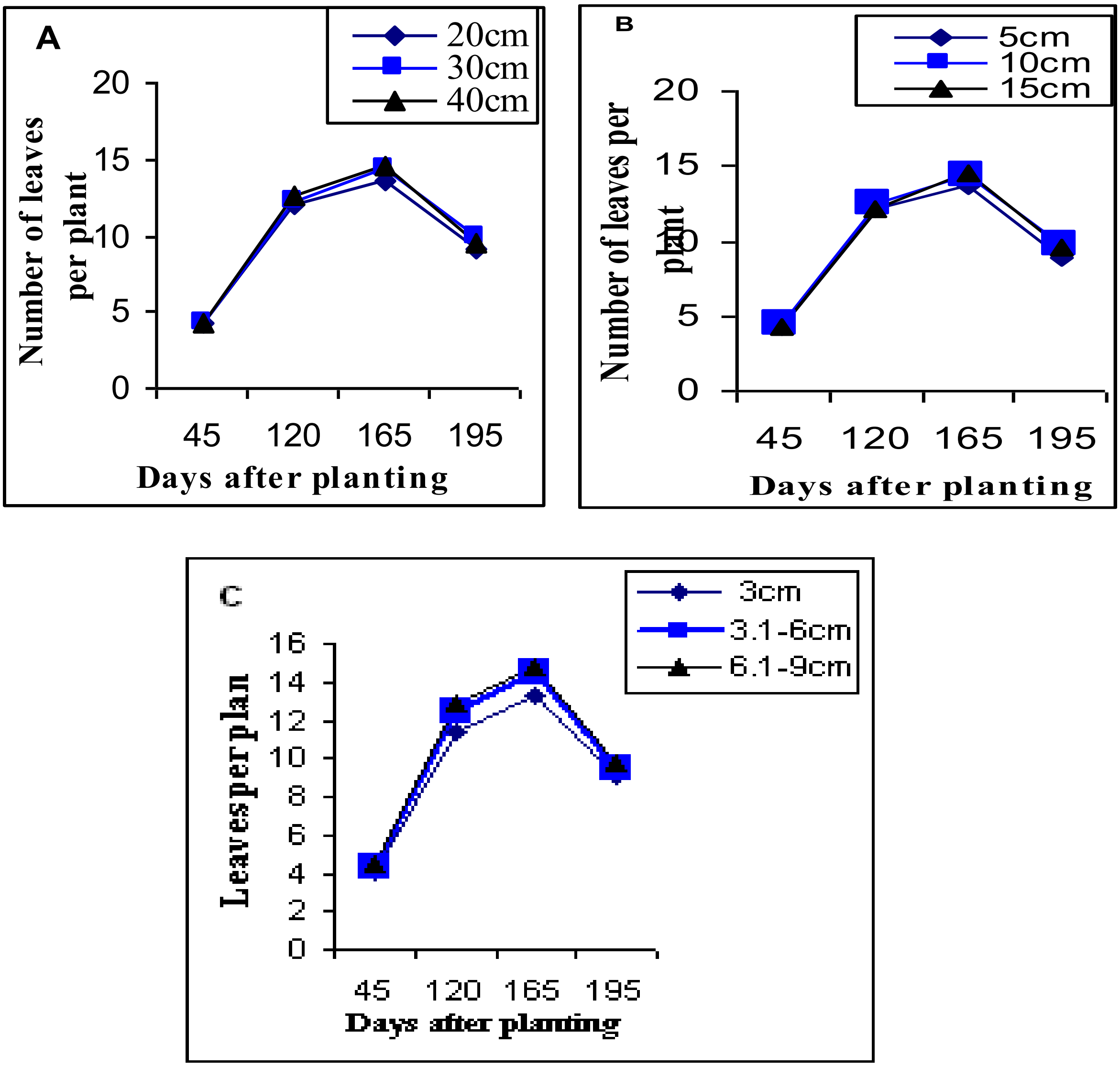


Figure 4. Number of leaves of ginger at different growth stages as influenced by, (A) inter row, (B) intra-row and (C) sett size per plant at Areka, 2008. 20, 30 and 40 cm were inter row spacing; 5, 10 and 15 cm were intra-row Spacing and ≤ 3 cm, 3.1- 6 cm and 6.1-9 cm were sett sizes.

3.6. Leaf length and width

Mean leaf length and width varied in relation to growth period. Regardless of inter and intra-row spacings as well as sett size, both leaf length and width were low at 45 DAP, increase with age of plants rapidly reaching a maximum at 165 DAP, and decline thereafter (Fig 5 and 6 A, B and C). The growth is initially slow while cell divisions generate cells that will form expanding in leaves until it approaches mature size and the growth rate decrease.

Inter row spacing had no significant ($P < 0.05$) effect on mean leaf length during the growth periods (Appendix 3); where as it had a significant ($P < 0.05$) effect on mean leaf width at 195 DAP (Appendix 3). At 195 DAP, the 40 cm inter row spacing scored significantly higher mean width per leaf (Fig 6A). On the other hand, intra-row spacing had no significant ($P < 0.05$) effect on mean leaf length at 195 DAP (Appendix 3). But, intra-row spacing had a significant ($P < 0.05$) effect on plant leaf width at 195 DAP (Appendix 3). During the period, intra-row 10 cm spacing scored higher mean width per leaf, which however, was not statistically different from 15 cm (Table 2). The results of the study are similar to the findings of Anteneh et al. (2008), Karye and Yakbu (2005), Khan et al. (2003) on ginger, garlic and onion, respectively and reported that those crops showed tendency to have increased length of leaf and width with increase in spacings. Similarly, Desta (2008) observed that inter and intra-row spacings had no significant ($P < 0.05$) effect on mean leaf length growth of garlic plant.

Sett size had no significant ($P < 0.05$) effect on mean leaf length at 195 DAP (Appendix 3) but it had a highly significant (P < 0.001) effect on mean leaf width (Appendix 3). Unlike to leaf length, it gave significantly higher mean leaf width than the small sett size but not statistically different from medium sett (Table 2).

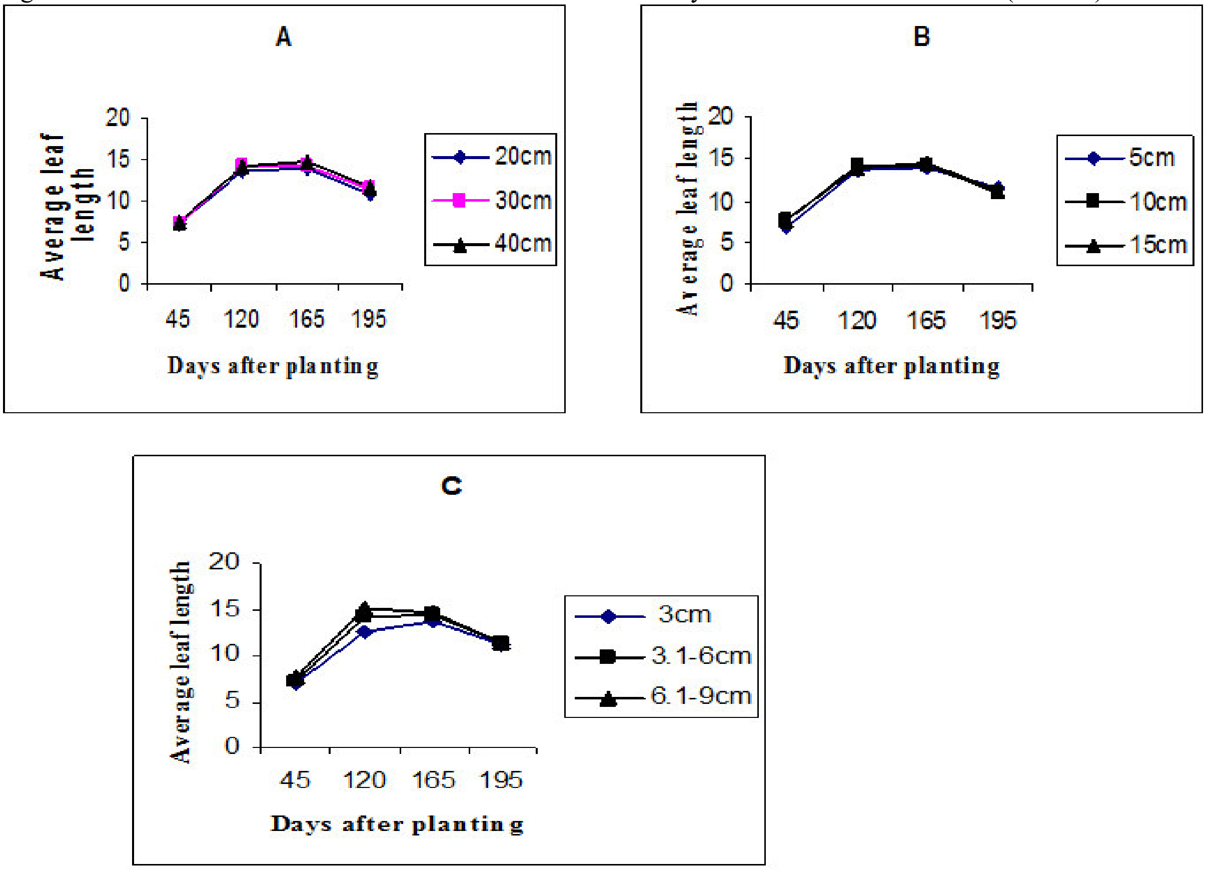


Figure 5. Average leaf length of ginger at different growth stages as influenced by (A) Inter row, (B) Intra-row and (C) Sett size at Areka 2008. 20, 30 and 40 cm were inter row spacings; 5, 10 and 15 cm were intra row spacing and ≤ 3 cm, 3.1- 6 cm and 6.1-9 cm were sett sizes.

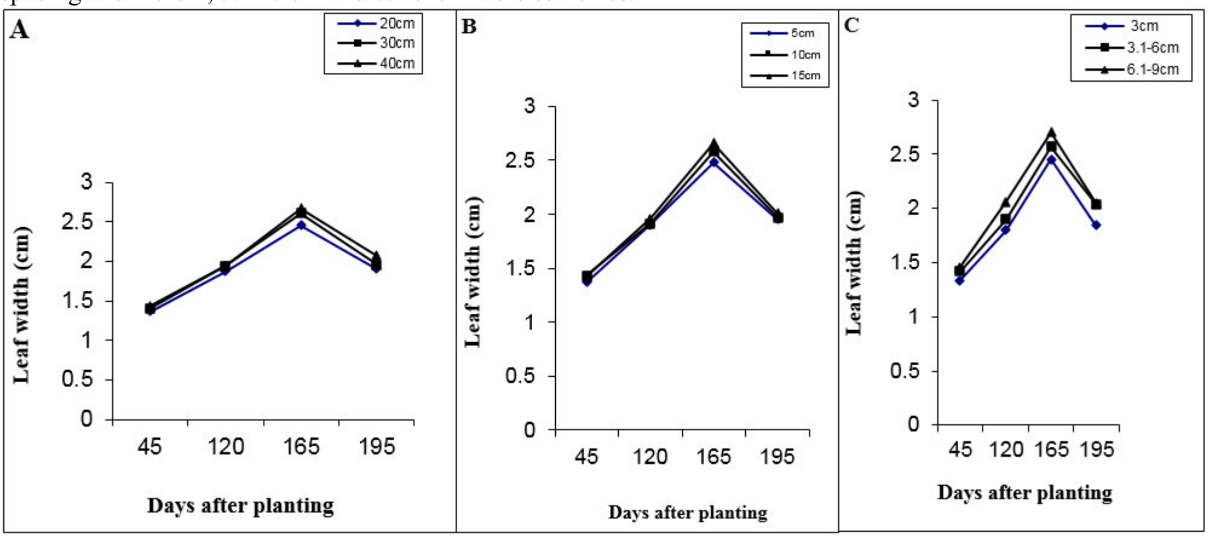


Figure 6. Average leaf width of ginger at different growth stages as influenced by (A) inter row, (B) intra-row and (c) sett size at Areka 2008. 20, 30 and 40 cm were inter row spacings; 5, 10 and 15 cm were intra row spacings and 3 cm, 3.1-6 cm and 6.1-9 cm were sett sizes.

3.7. Leaf area (LA)

The trend of leaf area in relation to the growth period is presented in Figure 7. Regardless of inter and intra-row spacings and sett size, leaf area increased sharply 45 DAP till 165 DAP and then declined (Figure 7).

Intra-row spacing had a highly significant (P < 0.01) effect on mean leaf area at 195 DAP (Appendix 5).

At a time, the 15 cm intra row spacing scored significantly higher (328.68 cm^2) mean leaf area per plant followed by 10 cm (315.15 cm^2). In general, 5 cm intra row spacing scored statistically and non-statistically lower mean leaf area per plant through out the entire growth stages (Table 2).

Sett size had a highly significant ($P < 0.01$) effect on mean leaf area per plant at 195 DAP (Appendix 5) the largest sett size scored significantly higher mean leaf area per plant followed by the medium sett size. Similarly, the medium sett size scored significantly higher mean leaf area per plant than the smallest sett size at 195 DAP (Table 2).

Mean leaf area per plant in ginger was affected by inter and intra-row spacings and sett size. Leaf area per plant increased with increased inter and intra-row spacings and reached a maximum at the widest spacing (Table 2 and Fig 7A and B). An increasing inter row spacing from 20 to 30 and 20 to 40 cm inter row spacing increased the mean (267.92, 333.79 and 318.79 cm^2) leaf area per plant by 19.73 and 15.96 %, respectively. The results of the study are similar with the work of Elzabeth (2007) and Mulugeta (2007) in garlic and taro, respectively. The same result was also reported by Yldz and Kazym (2002), on the effect of plant population densities on pepper. The possible reasons for decrease in mean leaf area with decrease in inter row and intra-row spacings might be due to more competition for resources, less light interception per plant that in turn resulted in reduced assimilation rate and limits leaf development. This is also supported by the highly significant and positive correlation leaf area with leaf number per plant ($r = 0.56$, $P < 0.0001$) (Appendix 6).

Type of planting materials (sett sizes) had a significant influence on leaf area per plant during entire growth periods (Appendix 3). Plants grown from the large sett size followed by medium sett sizes record significantly higher leaf area per plant throughout the growing periods followed by medium sett size (Table 2). Ginger at wider inter and intra-rows spacing and with large sett size were found to produce maximum leaf area per plant than the small sett size. Especially shoot grown from medium and large sett sizes were found to be vigorous and produce large number of leaves and leaf area at both per plant and per unit area in the experiment. The result of this study is in line with findings of Anteneh, et al. (2008) who reported that leaf area in ginger crop can be varied by using different cultivars and crop management. In similar line, Khalafalla (2001) reported that using different sett size of potato tuber significantly influenced leaf area, and it was increased with increased in sett sizes used.

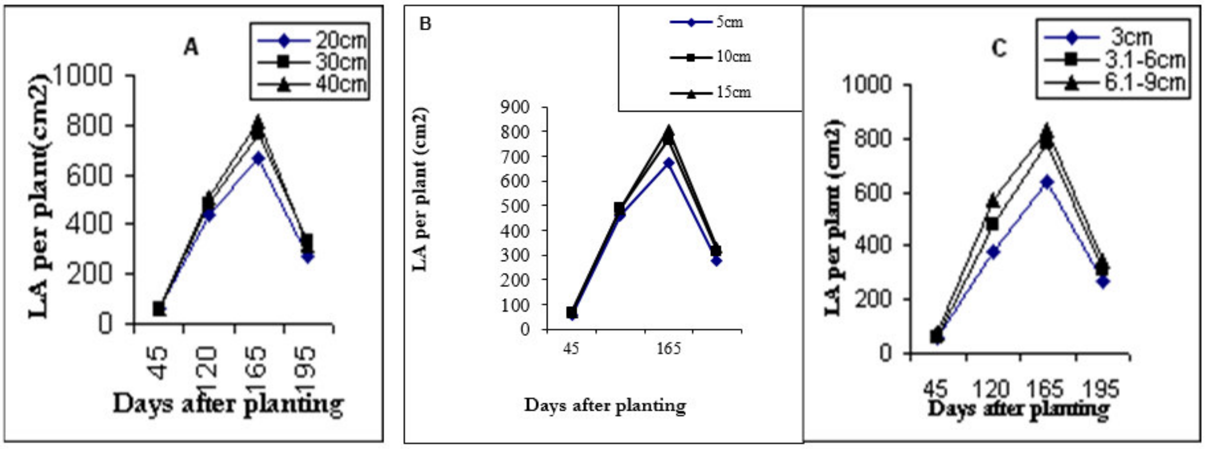


Figure 7. Mean leaf area of ginger at different growth stages as influenced by (A) inter row, (B) intra-row and (c) sett size at Areka 2008. 20, 30, and 40cm wer e inter row spacings; 5, 10 and 15cm were intra row spacings and ≤ 3cm, 3.1- 6cm and 6.1-9cm were sett sizes.

3.8. Leaf area index (LAI)

The trend of leaf area index in relation to the growth period is presented in Figure 8. Regardless inter and intra-row spacings and sett size, leaf area index increased sharply 45 DAP till 165 DAP and then declined. The decline of leaf area index after 165 DAP might be due to senescence of leaves associated with the remobilization of the stored metabolic from the leaf to the developing rhizomes; moreover, the details are reviewed in relation to spacing and sett size below.

Inter row spacing had a highly significant ($P < 0.01$) effect on mean leaf area index per plant at 195 DAP (Appendix 3). At this stage, the 20 cm inter row spacing scored significantly higher mean leaf area index per plant. Similarly, 30 cm inter row spacing scored higher mean leaf area index than 40 cm inter row spacing (Table 2). Intra-row spacing had a significant ($P < 0.05$) effect on mean leaf area index at maturity (Appendix 3). The 5 cm intra row spacing scored significantly higher (1.94) mean leaf area index per plant followed by 10 cm intra row intra-row spacing (1.12) (Table 2).

Sett size had a highly significant ($P < 0.001$) effect on mean leaf area index at 195 DAP and also it had influenced significantly (P < 0.05) at 45 DAP (Appendix 3). The largest sett size scored significantly higher mean (1.42) LAI per plant. Similarly, the medium sett size scored significantly higher mean (1.3) LAI at 195 DAP growth period than the smallest sett size (1.1) (Table 2).

LAI in ginger was affected by inter and intra-row spacings and sett size at 195 DAP. Mean leaf area index increased with decrease in inter and intra-row spacings. The maximum mean leaf area index was obtained by the narrowest inter and intra-rows spacing (20 & 5 cm). The result of this study is in line with the findings of Mihret (2006) and Springer and Gillen (2007) who reported increment of leaf area index on potato and bluestem plant, respectively. In a similar way, an increase in leaf area index with increase in plant population has been reported by Shih and Snyder (1984) and Mulugeta (2007) on taro; Enyi (1967) on cocoyam. For the increasing in LAI with increased plant population (decreased spacing) densities, the most likely explanation has been given by Loss et al (1998) as high population density resulted in significantly earlier canopy closure, larger green LAI and providing larger surface area for more solar radiation interception resulting high net photosynthesis, more dry matter accumulation during the early vegetative growth and greater yield than treatments where a low plant density.

Rhizome sett size had a highly significant (P ≤ 0.001) effect on mean leaf area index of plant (Appendix 4). The highest mean leaf area index of plant during 195 DAP was produced by sett with 6.1- 9 cm sizes. The result agrees with the earlier findings of Terefe (2003) who reported that sweet potato grown from larger planting material gave higher mean LAI. Similarly, Onwueme (1978b) reported that leaf area index per plant was higher for large-sett size than for small-sett size for yam; and also Khalafalla (2001) found that seed size significantly and positively affected leaf area index of potato. The possible reason for increasing LAI with increase in sett size could be due to the fact that large sett size emerged earlier (Table 1) and then early canopy closure leading to more number of tillers with greater leaves number (Table 2) and LAI have highly significant and positive correlation with number of leaves (r = 0.39, P < 0.001), plant height (r = 0.62, P < 0.001) and tillers per plant (r = 0.31, P < 0.01 (Appendix 6). Thus resulted via large sett size, make the crop successively to produce higher LAI (Table 2).

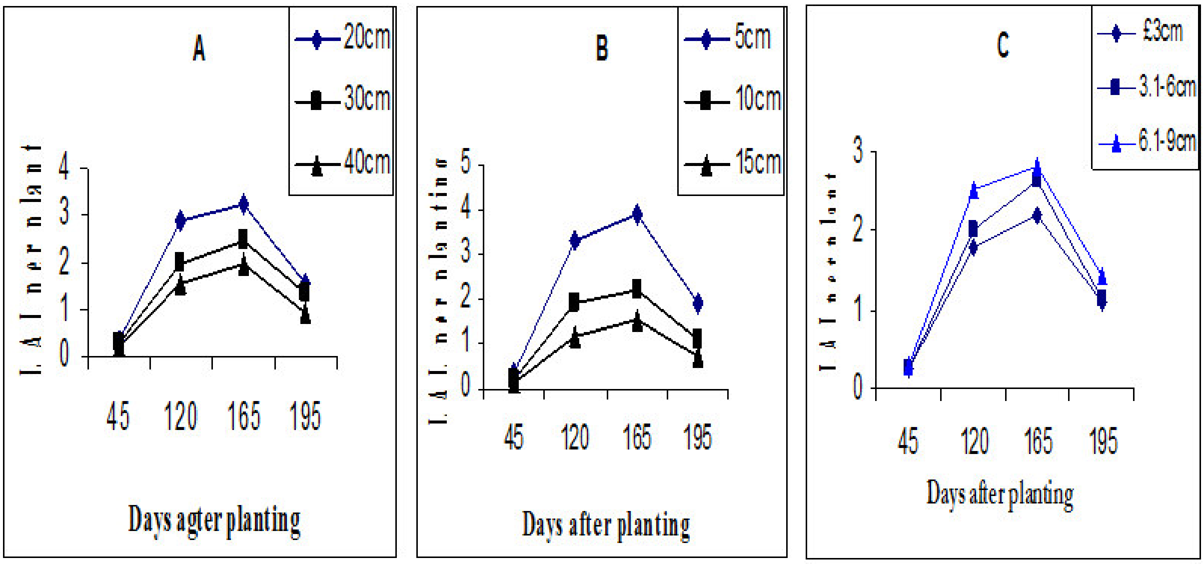


Figure 8. Mean leaf area index of ginger at different growth stages as influenced by (A) inter row, (B) intra-row and (C) sett size at Areka 2008. 20, 20, 30 and 40 cm were inter row spacing; 5, 10 and 15 cm were intra row spacing and ≤ 3 cm, 3.1- 6 cm and 6.1-9 cm were sett sizes.

Table 2. Main effect of means for growth parameters during maturity as affected by inter row, intra-row spacing and rhizome seed pieces at Areka, 2008

Treatments	TPP	PH (cm)	NL	LL (cm)	LW (cm)	LA (cm^2)	LAI	SDW (g)
INRO (cm)								
20	1.13b	38.53	9.11	10.73b	1.90b	267.92b	1.57a	3.24
30	1.27a	41.4	9.82	11.48ab	1.96b	333.79a	1.33b	3.77
40	1.26a	42.84	9.43	11.66b	2.07a	318.79a	0.94c	3.69
LSD	0.07	NS	NS	0.87	0.09	50.77	0.23	NS
CV(a)	7.40	16.58	10.57	10.23	6.32	21.90	24.00	25.15
INRA (cm)								
5	0.99b	39.3b	8.93b	11.51	1.95	276.27b	1.94a	3.402b
10	1.34a	41.72a	9.82a	11.04	1.97	315.55a	1.12b	3.78a
15	1.33a	41.76a	9.6a	11.31	2.01	328.68a	0.77c	3.52ab
LSD	0.09	1.84	0.41	NS	NS	33.93	0.16	0.26
CV(b)	13.07	7.56	7.30	13.20	7.38	18.65	25.80	12.40
SET (cm)								
≤ 3	1.11b	38.76c	9.05b	11.11	1.84b	265.89c	1.10c	3.169c
3.1 – 6	1.30a	41.10b	9.52a	11.31	2.04a	312.94b	1.30b	3.61b
6.1 – 9	1.25a	42.92a	9.78a	11.44	2.05a	341.67a	1.42a	3.93a
LSD	0.06	1.58	0.29	NS	0.06	26.64	0.12	0.26
CV (c)	9.42	7.01	5.58	10.33	5.77	15.73	17.24	13.06

TPP- Number of tillers per plant, PH- plant height, NL- number of leaves per plant, LL - leaf length, LW- leaf width, LA- leaf area, LAI- leaf area index, SDW- above ground shoot dry weight per plant.

3.9. Plant shoots dry weight

Inter row spacing had no significant effect on mean shoot dry weight per plant at 195 DAP (Appendix 4). Intra-row spacing had significant ($P < 0.001$) effect on mean dry weight at 195 DAP (Appendix 4). At this time; 10 cm intra row spacing scored higher mean shoot dry weight per plant, which however, was not statistically different from 15 cm spacing. The 5 cm intra row spacing scored lower mean dry weight per plant at 165 DAP (Table 3).

Sett size had a highly significant ($P < 0.001$) effect on mean shoot dry weight per plant at 45, 120, 165 and 195 DAP (Appendix 4). During the entire growth periods, the largest sett size scored significantly higher mean dry weight per plant followed by the medium sett size (Table 3).

Dry weight in ginger was affected by intra-row spacing and sett size. Mean shoot dry weight per plant increased with increase in intra-row spacing (Table 3). The reason for increase in dry matter per plant at wider intra-row spacing could be the presence of strong and significant correlation of dry weight with tillers per plant, number of leaves per plant, leaf area and leaf area index. This can be explained by larger number of tillers and leaves related increasing in leaf area thereby plants enable to produce high primary products (carbohydrate) via utilization of resources with less competition compared to decreased intra-rows. This result is agree with findings of Elezabeth (2007) who reported dry weight per plant in garlic increased with increase in inter and intra-row spacing.

The interaction effects of inter and intra-rows spacing were significant on dry weight per plant at 120 and 165 DAP (Appendix 3). The highest (13.83 g) was recorded from 40 cm x 15 cm combination followed by 40 cm x 10 cm and 30 cm x 15 cm at 120 DAP and similarly, 40 cm x 15 and 30 x 15 cm inter and intra rows combinations were scored the highest (30. 04 and 30.03 g) at 165 DAP followed by 40 cm x 10 cm inter and intra row spacings, respectively (Table 3).

Sett sizes had highly significant ($P < 0.001$) effect on dry matter content per plant at all DAP growth measurements. The minimum mean shoot dry weight per plant (1.11g) was obtained at 45 DAP from the lowest seed pieces, whereas the maximum (30.43 g) was from the largest seed piece at 165 DAP (Table 3). The result of the study are similar to the findings of Girma and Digafie (2004) and Ravadran and Bacu (2005) who investigated the effect of rhizome seed pieces having and formed a linear and significant increase in most vegetative growth parameters.

Table 3. Main effect of means for shoot dry weight per plant as affected by inter row, intra-row spacing and rhizome seed pieces at Areka, 2008.

Treatments	45 DAP	120 DAP	165 DAP	195 DAP
	Shoot dry weight			
Inter row(cm)				
20	1.13	11.59	27.5	3.24
30	1.33	12.85	28.74	3.77
40	1.31	13.42	29.6	3.69
LSD **0.05**	NS	0.61	2.03	NS
CV(a)%	23.87	6.38	9.37	25.15
Intra-row (cm)				
5	1.21	12.44	27.85	3.402b
10	1.23	12.65	29.19	3.78a
15	1.32	12.77	28.8	3.52ab
LSD **0.05**	NS	0.32	0.55	0.26
CV(b)%	15.91	4.21	3.27	12.40
Sett size(cm)				
≤ 3	1.11c	11.63c	26.41c	3.169c
3.1 – 6	1.26b	12.45b	29.0b	3.61b
6.1 – 9	1.39a	13.77a	30.43a	3.93a
LSD **0.05**	0.09	0.28	0.78	0.26
CV(c)%	13.55	3.97	4.96	13.06

Values followed by the same letter (s) with in a column are not significantly different at P ≤ 0.05. NS – non significant

Table 4. Interaction effects of intra-row spacing by sett size on plant shoot dry weight at 120 & 165 DAP at Areka, 2008

Inter row	Intra row	Shoot dry weight (g) 120 DAP	Shoot dry weight (g) 165 DAP
20 cm	5 cm	11.72	27.21
40 cm	5 cm	12.72	28.97
40 cm	10cm	13.72	30.04
40 cm	15cm	13.83	29.81
30 cm	5 cm	12.87	27.38
30 cm	10cm	12.70	28.80
30 cm	15cm	12.98	30.03
20 cm	10cm	11.55	28.73
20 cm	15cm	11.50	26.56
CV (%)		3.97	13.06

3.10. Rhizome yield

3.10.1. Rhizome fresh yield per plant

Inter row spacing had a significant (P ≤ 0. 05) effect on mean fresh rhizome yield per plant (Appendix 5). The 40 cm inter row spacing scored significantly higher (64.21g) mean fresh rhizome yield per plant, which however, was not statistically different from 30 cm spacing (table 6). The 30 cm inter row spacing scored significant higher mean fresh rhizome yield per plant than the 20 cm spacing.

Intra-row spacing had highly significant (P < 0. 001) effect on mean rhizome fresh yield per plant (Appendix 5). The 15 cm intra row spacing scored significantly higher mean fresh rhizome yield per plant; and the 10 cm intra row spacing scored significantly higher mean fresh rhizome yield per plant than the 5 cm intra-row spacing.

Sett size had significant (P < 0.001) effect on mean rhizome fresh yield per plant (Appendix 5). The sett size 6.1- 9 cm length scored significantly higher mean fresh rhizome yield per plant than sett sizes of ≤ 3.0 and 3.1- 6.0 cm length. Similarly, sett size 3.1- 6.0 cm scored significantly higher mean fresh rhizome yield per plant than sett sizes ≤ 3.0 cm (Table 5).

In the present study, mean rhizome fresh yield per plant in ginger was affected by inter and intra-row spacings and sett size. Increasing inter row spacing from 20 to 40 cm increases mean rhizome fresh yield per plant by 14 % and 18.5 %, respectively. Similarly, increasing intra-row spacing from 5 – 10 cm and 5 – 15 cm increased the mean fresh rhizome yield by 13.47 and 18.08 %, respectively. The results of the study are in line with findings of Tesfaye et al. (1999) who reported in potato that the marketable and total tuber yield, stem number per plant and different tuber size grades per plant are significantly (P < 0.01) influenced by inter row spacing. In addition, Edossa et al. (1997) suggested that the wider the inter row and/ or intra-row spacings, the higher the yield per plant, but the lower the plant population and, therefore, the lower the yield per unit of land was.

According to Hartmann et al. (2002), while selecting a seed, quality of a seed is one of the major criteria to get optimum yield and a quality of product. The result in this experiment showed that different sized seed pieces had highly significant (P < 0.001) and positive effect on rhizome yield per plant (Appendix 5). Mean rhizome fresh yield per plant increased with increase in sett size. Over the range of sett size used, the highest yield per plant (73.59 g) was produced by large sett size and it was higher by 32.55 and 26.3 % than the small and medium sizes, respectively. The results reported here are in agreement with findings of Pruthi (1998) on ginger, Tesfaye, et al. (1999) on potato; Misra and Nedunchezhezhiyan (2004) on yam. They reported in the same way that as the seed pieces increase, the yield per plant as well as per unit area was increased; and inversely, an increasing in spacing resulted in decreased yield per unit area. The possible reason for the result obtained might be that the ability for larger sett sizes to produce a vigorous initial growth of organs due to its available food reserves and an advantage that was maintained through the growing season and that lead to final higher yield.

Table 5. Main effect of means for Yield, yield components and harvest index of ginger as affected by inter row, intra-row spacing and rhizome seed pieces at Areka, in 2008.

Treatments	RFW/ha (kg)	DWP500 (g)	RDW/ha (kg)	TBM/ha (kg)	RL (cm)	RW (cm)	RF/P	RFW/P (g)	HI
INTER (cm)									
20	36429.6a	123.561	9067.9	41363	9.36b	4.23b	6.01c	52.33b	0.87a
30	34267.2a	127.015	8803.8	40370	11.07a	4.65a	6.84b	60.85a	0.84b
40	27356.9b	124.988	6921.1	33531	11.23a	4.42ab	7.39a	64.21a	0.81b
LSD	2339	NS	1214.7	3511.5	1.39	0.27	0.34	5.85	0.03
CV(a)%	9.47	10.02	19.45	12.09	17.44	8.15	6.59	13.10	5.23
INTRA (cm)									
5	31719	124.17	7916.9	37272b	10.1b	4.28	6.23b	52.54b	0.843
10	34322	126.70	8813.8	40495a	10.8a	4.58	6.92a	60.72ab	0.841
15	32013	124.70	8062	37497b	10.8a	4.44	7.1a	64.14a	0.846
LSD	Ns	NS	NS	2800.20	0.55	0.24	0.33	2.06	NS
CV(b)%	13.87	10.77	20.08	12.29	8.73	9.00	8.14	5.87	3.57
SET (cm)									
≤ 3	23350c	117.17b	5472.8	28480	9.67c	4.12b	5.53c	49.64c	0.818c
3.1 – 6	32895b	130.67a	8619.4	38898	10.70b	4.59a	6.8b	54.17b	0.843b
6.1 – 9	41808a	127.72a	10700.6	47886	11.29a	4.58a	7.92a	73.59a	0.868a
LSD	2365.2	6.5354	824.44	2558.5	0.51	0.23	0.22	1.94	0.01
CV (%)	13.11	9.46	18.07	12.06	8.78	9.42	5.81	5.93	2.83

RFW/ha – Rhizome fresh weight per hectare, DW500 – dry weight of 500 g fresh weight, RDW/ha – rhizome dry weight per hectare, TBM/ha – total biomass per hectare, RLpnt – mean rhizome length, RW – mean rhizome width , RF/P – rhizome fingers per plant, RFW/P – rhizome yield fresh weight per plant.

3.10.2. Total fresh rhizome yield

Inter row spacing had a significant (P < 0.001) effect on mean total fresh rhizome yield per hectare (Appendix 5).The highest mean fresh rhizome yield (36429.6 kgha^{-1}) was produced at 20 cm inter row spacing, which was highly significant than the yield (27356.9 kg ha^{-1}) obtained from 40 cm inter row spacing, however, 20 cm inter row spacing was not statistically different from the yield (34267.2 kg ha^{-1}) recorded at 30 cm spacing (Table 5). Intra row spacing had no significant (P< 0.05) effect on mean rhizome fresh yield per hectare (Appendix 5). Non statistically different higher mean rhizome fresh yield per hectare was obtained from 10 cm intra row spacing than the 5 and 15 cm spacing.

Sett size had a highly significant (P < 0.001) effect on mean rhizome fresh yield per hectare (Table 5). The largest sett size produced significantly the highest (41808 kgha^{-1}) mean fresh rhizome yield; similarly the medium sett size produced significantly higher (32895kg ha^{-1}) rhizome yield than the smallest sett size (Table 5).

Mean fresh rhizome yield per hectare in ginger was affected by inter row spacing and sett size. Rhizome fresh yield per hectare increased with decrease in inter row spacing. Increasing inter row spacing from 20 to 40 cm decreased mean rhizome fresh yield per hectare by 24.91 %; and similarly, increasing inter row spacing from 30 to 40 cm deceased the mean rhizome fresh yield per hectare by 20.17 %. The results of the study are similar to the findings of Weiss (2002), Girma and Digafie (2004) and Ravindran and Bacu (2005) on ginger; Hossan (1978) and Chaudhry (1990) on onion, who reported that an increasing number of rows per unit area increase total yield per hectare and widening inter row spacings also decreased total yield per hectare. Similarly, Karaye and Yakubu (2005) reported that the use of highest close spacings would maximize the yield on garlic. Rhizome fresh yield per hectare increased with increase in seed pieces size. As sett size increase from ≤ 3 to 3.1- 6 cm, and 6 - 6.1- 9 cm rhizome fresh yield ha^{-1} increased by 29 % and 21.32 %, respectively. The result obtained in the study are very related with the findings of Leverington (1983), Weiss (2002), Girma and Digafie (2004) and Ravindran and Bacu (2005) on ginger; Onwueme (1978b) on taro; Festus et al. (1983) on yam; Tesfaye et al. (1999) on potato. In these crops larger sett sizes produce higher yield than the smaller sett size per hectare. The possible reasons for the increasing yield per hectare might have been due to having the greater weight of the sett size so used the seedling to established well due its more reserve foods that may lead to early canopy closure, maximum leaf area and leaf area index perhaps in turn which help the plant to have good stand and produce more yield.

The maximum (41808 kgha^{-1}) mean rhizome fresh yield per hectare was achieved with 6.1 cm - 9.00 cm sett size irrespective to inter and intra-row spacings (Table 5). The result is similar with national recommendation which was sett size 6.1 - 9 cm length (Girma and Degifie, 2004). The mean fresh rhizome yield obtained in this study is higher than the national/ regional average (150 qt ha^{-1}) (SNNPRS bureau of Agriculture and Rural Development, 2007) and Boloso Sore (200 qt ha^{-1}) (Woreda Agriculture and Rural Development office). It is also higher than the yield in experimental condition at Tepi Agricultural research sub center (347 qt ha^{-1}) (Girma and Degafie, 2004). However, it is by far less than that yield reported by Leverington (1983) (120 tha^{-1}) and Weiss (2002) (150 tha^{-1}). The possible reason for the increment in yield per hectare might be due to the appropriated in sett size, cultivars and proper in spacing used. Moreover, other such as edaphic, climatic factors and high amount of LAI and TBM conversion to economical yield, size of rhizome length and width with number of fingers are pronounced components to contribute for the higher yield in this experiment. All the interactions among treatments (inter row spacing x intra-row spacing, inter row spacing x sett size, intra-row spacing x sett size and inter row spacing x intra-row spacing x sett size) did not significantly influenced mean fresh rhizome yield per hectare (Appendix 5).

3.10.3. Rhizome dry weight

Inter row spacing had no significant (P < 0.05) effect on mean rhizome dry weight of 500g fresh wt (Appendix 5). Intra-row spacing had no significant (P < 0.05) effect on mean rhizome dry weight of 500g fresh wt and similarly on rhizome dry weight per hectare (Appendix 5).

Sett size had a significant effect (P < 0.001) on dry weights of 500g fresh wt (Appendix 5). The sett with 3.1 to 6 cm size scored higher (130.67 g) mean rhizome dry weight per plant, which however, was not statistically different from the largest sett size (Table 5). Mean rhizome dry weights of 500g fresh wt in ginger thus affected by sett size. The results of the study are in line to the findings of Hassan (1978) and Muhammad (2004) and Elezabeth (2007) who did work on onion (the former two) and garlic (latter one) and reported that the bulb dry weight increased with increased inter row spacing.

Interaction of inter row spacing and sett size on ginger rhizome dry yield per hectare was significant (Appendix 5). The interaction showed that difference in rhizome dried yield per hectare among three levels of inter row spacings were greater at largest sett size (table 5). Interaction of inter row 20 cm and sett size with 6.1 - 9 cm resulted higher rhizome dried yield per hectare than 40 cm and 30 cm with large sett size. Rhizome dried yield of 13543.8 and 11318.7 kg per hectare was obtained from 20 cm by sett size 61-9cm length and 30 cm by 6.1-9 cm length sett size. It was observed that the medium sett size gave higher rhizome dried yield than others in using 30 cm inter row spacing (Table 5). Possible reason for increase in mean rhizome dry weight might be the bigger seed pieces attained of more reserve food that lead to early canopy closure, maximum leaf area and leaf area index that enhance the production of bigger weight of rhizomes, which in turn leads to the more dry weight accumulation to have. The result of the study is in line to the findings of Ameyaw et al. (1991) in taro who reported that the bigger the corm size, the more is the dry matter accumulation with high economic yield harvest. Dry weight per hectare has highly significant and positive correlation with leaves number ($r = 0.40$, $P < 0.001$), rhizome length ($r = 0.44$, $P < 0.001$), LAI ($r = 0.40$, $P < 0.001$) and rhizome fresh weight/ha ($r = 0.47$, $P < 0.001$) (Appendix 6) which helps to explain the increment of rhizome dry weight in the experiment.

Table 6. Interaction effect of inter row spacing and sett size on ginger rhizome dry yield per hectare at Areka, 2008

Inter row spacing (cm)	Sett size (cm)	Rhizome dried yield (kgha^{-1})
20	≤ 3.00	6468. 2
20	3.1 - 6.00	8961.4
20	6.1 - 9.00	13543.8
30	≤ 3.00	5866.2
30	3.1 - 6.00	10726.4
30	6.1 - 9.00	11318.7
40	≤ 3.00	5584.0
40	3.1 - 6.00	7670.3
40	6.1 - 9.00	9009.0
	CV %	18.10

3.11. Crop yield components

3.11.1. Rhizome length

Inter row spacing had a significant ($P < 0.05$) effect on mean rhizome length (Appendix 5). The highest (11.23 cm) rhizome length was produced at widest (40 cm) inter- row spacing however, it was not statistically different from 30 cm inter row spacing. The lowest (9.36 cm) was recorded at narrowest (20 cm) inter row spacing (Table 5). Intra-row spacing had significant ($P<0.05$) effect on mean rhizome length per plant (Appendix 5). The highest (10.8cm) mean rhizome length was produced at 10 cm intra-row spacing, whereas the lowest (10.06cm) was recorded at narrowest (5 cm) spacing.

The effect of sett size was highly significant ($P < 0.001$) on rhizome length (Appendix 5). The sett with 6.1 - 9 cm size scored significantly higher (11.29 cm) mean rhizome length followed by sett with 3.1 – 6 cm size, while the sett with ≤ 3 cm size (12.13 g) scored significantly low (9.67 cm) mean rhizome length (Table 5).

Mean rhizome length in ginger was affected by inter and intra- row spacings and sett size. Mean rhizome length increased with increase in inter and intra-row spacings. Increasing inter and intra-row spacings from 20 - 40 cm increased mean rhizome length per plant by 15.45 % and 16.15 %, respectively. Similarly, increasing intra-row spacing from 5 to 10 cm and 5 to 15 cm increased the mean rhizome length per plant by 6.85 % and 6.77 %, respectively. The result of the study are similar to the findings of Castellanos, et al. (2004) and Chaudhary et al. (1990) who recorded higher bulb diameter and length in garlic and onion, respectively.

Mean rhizome length per plant increased with increase in sett size. Increasing sett size from ≤ 3 to 3.1 – 6 cm and ≤ 3 cm to 6.1 – 9 cm increased mean rhizome length by 10.28 and 14.97 %, respectively. The result is similar to the findings of Weiss (2002), Girma and Digafie (2004) on ginger; Castellanos et al. (2004) on garlic; Chaudhry et al. (1990) on onion, who reported higher length of the subterranean organ were attained with the higher degree of sett sizes. The possible reason for the increasing in rhizome length might be associated with seed size that accumulated reserve foods, which enable plants to have proper growth and latter on made them to produce appropriate length of rhizome. On the other hand, rhizome length was correlated highly significantly with number of tillers per plant (r=0. 41, P < 0. 001) and leaf per plant (r= 0. 56, P <0. 001) and leaf area index (r= 0. 53, P < 0. 001), it was also significantly correlated with plant height (r= 0.23, P < 0.o5). The interaction effects of inter row spacing by intra row, inter row by sett size, and intra rows by sett size was non significant on rhizome length ($P < 0.05$) (Appendix 5).

3.11.2. Rhizome width

Inter row spacing had a significant ($P < 0.05$) effect on mean rhizome width (Appendix 5). The 30 cm inter row spacing scored higher (4.65 cm) mean rhizome width per plant, which however, was not statistically different from 40 cm spacing. The 20 cm inter row spacing scored significantly low mean rhizome diameter per plant (Table 5). Intra-row spacing had no significant ($P < 0.05$) effect on mean rhizome width per plant (Appendix 5).

Sett size had a highly significant ($P < 0.001$) effect on mean rhizome width (Appendix 5). Both sett with 3.1 – 6 cm and 6.1 -9.00 cm size scored significantly higher mean rhizome width than sett with ≤ 3 cm size (Table 5).

Mean rhizome width in ginger was affected by inter row spacing and sett size. Mean rhizome width increased with increase the inter row spacing from 20 to 30 cm by 9.03 %. The result of the study are similar to the findings of Ravandran and Bacu (2005) who reported that rhizome length and width of ginger increased linearly with increased spacing used until optimum, in addition, Castellanos et al (2004), University of Minnesota, (1999), Chaudhry et al (1990) indicated that higher diameter of underground garlic bulbs were attained with increased spacing (decreased plants density) than decreased spacing. Geleta (1992) reported that lower population density produce higher tuber diameter of sweet potato. The possible reason for increasing in rhizome width with increase in spacing might be reduced competition between the neighboring plants due to the increasing free spacing surround the plant.

Mean rhizome diameter per plant increased with increase in sett size. Over the range of sett size used, increasing sett size from ≤ 3 cm (12.13 g) to – 9 cm increased mean rhizome length by 10.24 % and 10.04 %, respectively. The result agree with Whiley (1981) who reported the size of sett pieces of ginger rhizome significantly influenced the yield, yield components such as rhizome length, width of the crop as well as other growth parameters; and similarly Momoh and Zhou (2001); Hossain et al. 2003; Ahmed (1987); Onwueme (1973); Onwueme (1978a) and Onwueme, (1999) reported on oilseed, garlic, sweet potato, yam and taro that the crops growth and yield as affected significantly. The possible reason for the effect of the larger sett size might be the more reserve food, would help to produce a vigorous initial growth that may leading to higher final sett lengths, width and total yield, because rhizome length is highly significantly correlated with tillers per plant($r= 0.29$, $P <0.01$), plant height ($r= 0.33$, $P< 0.01$) (Appendix 6).

3.11.3. Rhizome finger per plant

Inter row spacing had a highly significant ($P < 0.001$) effect on mean number of fingers per plant (Appendix 5). The 40 cm inter row spacing scored higher (7.39 cm) mean rhizome finger per plant. The 30 cm inter row spacing scored significantly higher mean rhizome finger per plant than 20 cm but not different from 40 cm spacing (Table 5).

Intra-row spacing had a significant ($P < 0.001$) effect on mean number of fingers per plant (Appendix 5). The 15 cm intra-row spacing scored higher mean rhizome finger per plant. The 10 cm intra-row spacing scored higher mean rhizome finger per plant than 5 cm but not from 15 cm spacing. The 5 cm intra row spacing scored significantly low mean rhizome fingers per plant (Table 5).

Sett size had significant ($P < 0.001$) effect on mean number of fingers per plant (Appendix 5). The largest sized sett (6.1 - 9.00 cm) scored significantly higher mean rhizome fingers per plant. Similarly the sett size 3.1 – 6 cm scored significantly higher fingers per plant than the smallest (≤ 3 cm) sett size (Table 5).

Mean rhizome fingers per plant in ginger is thus affected by inter and intra-row spacings and sett size. Mean rhizome fingers per plant in ginger increased with increasing inter and intra-row spacings. Increasing inter row spacing from 20 to 40 cm increased the mean rhizome fingers per plant by 12.13 and 18.67 %, respectively. Similarly, increasing intra-row spacing from 5 to 10 cm and 15 cm increased the mean rhizome fingers per plant by 9.97 and 12.25 %, respectively. The result is similar to the findings of Naurai (1994) who reported increasing in cloves number per bulb with increase in inter and intra-row spacings. The possible reason for increasing in rhizome fingers per plant with increase in spacing might be available spacing the rhizome to produce fingers and reduced competition among the neighboring plants due to the increasing free spacing per plant.

Rhizome fingers per plant increased with increase in sett size. Over the range of sett size used increasing from ≤ 3 cm to 3.1 - 6.00 cm and to 6.1 - 9.00 cm, and 3.1 - 6.00 cm to 6.1 - 9.00 cm increased the mean rhizome fingers per plant by 18.68, 30.18 and 14.14 %, respectively. These findings are in close conformity with the work of purseglove et al. (1981) who reported as ginger close spacing (higher population densities) to give the highest yield per unit area, similarly, and Girma and Digafie (2004) who conducted a three years trials at Bebeka for two seasons and they reported that the close spacing (higher population densities) to give the highest yield per unit area, similarly distant (wider) inter and intra-rows yields high number of fingers per plant. In line with this Edossa et al. (1997) trials were conducted at Jimma research center to determine the inter row and intra-row spacings requirement of taro substantiate the findings of current work on ginger with similar result. Puiattit, et al. (2003) found that number of corm and cormels increased with increased sett size, Harris (1978) and Spence and Ahmad (1970) reported as tubers number per plant increased as inter and intra-rows spacing increased. Rhizome finger has a significant and positive correlation with tillers peer plant ($r = 0.43$, $P < 0.001$), leaf area ($r = 0.31$, $P < 0.01$) and LAI ($r = 0. 57$, $P < 0.001$) (Appendix 6) which help to explain the increase of rhizome finger per plant.

3.11.4. Total biomass

Intra-row spacing had significant ($P < 0.05$) effect on mean total biomass per hectare (Appendix 5). The 10 cm intra-row spacing scored significantly higher mean total biomass per ha^{-1} than from 15 cm intra-row spacing that scored non statistically higher mean of total biomass than 5 cm.

The interaction effect of inter row spacing by sett size and inter & intra-row spacing by sett size was found significant on TBM per ha (Appendix 5). The highest total biomass was obtained with sett 6.1-9 cm sizes at 20 cm and the lowest was found with sett ≤ 3 cm sizes at 40 cm per ha^{-1} (Table 7). Generally, the interaction indicated that the difference in TBM among the different spacing was more pronounced at the 20 cm (highest population plants per ha^{-1}) spacing and with large sett (6. 1 – 9. 00 cm) size.

Table 7. Interaction effect of inter row spacing by sett size and intra-row spacing by sett size on ginger total biomass (kgha^{-1}) at Areka, 2008

	Sett size (cm)		
Spacing (cm)	≤ 3.00	3.1 - 6	6.1 – 9
Inter row 20	30200.0	37156.2	50092.3
30	27888.1	42766.1	46760.4
40	26350.5	34962.3	38173.2
Intra-row 5	24307.4	33156.1	43626.3
10	28033.5	39276.5	44099.5
15	23098.2	34561.9	45933.5
CV%	12.06	12.06	

3.11.5. Harvest index

There was statistically significant ($P < 0.05$) variation among the inter rows spacing in harvest index (Appendix 5). The narrowest (20 cm) inter row spacing scored significantly higher mean harvest index followed by 30 and 40 cm inter row spacing (Table 5). Intra-row spacing had no significant ($P < 0.05$) effect on mean harvest index of ginger in this experiment (Appendix 5). However, there was slight increase in harvest index with decrease in intra-row spacing (Table 5).

Sett size had a highly significant ($P < 0.001$) effect on mean harvest index of ginger (Appendix 5). The largest sett size (6.1- 9.00 cm) scored significantly higher mean harvest index followed by the medium sett size which was also statistically significant from the smallest sett size. The ≤ 3 cm sett size scored significantly low mean harvest index (Table 5).

Harvest index in ginger thus affected by inter row spacing and sett size. Harvest index increase with decreased inter row spacing. Increasing inter row spacing from 20 to 40 and 30 to 40 decrease harvest index by 6.9 and 3.57 %, respectively. The result was in line with the findings of Elzabeth (2007) on garlic, that harvest index was slightly decreased with increased inter row spacing and significantly increased at lowest intra-row spacing (with increased plant density). In addition, Jahan and Hamid (2004) reported that an increase in harvest index with plant density increase in mung bean. The possible reason for decreased harvest index per unit area with increased inter rows might be decreasing in plant population per unit area that reduced the economic yield of the crop due to sparsely populated condition yield can be decreased.

Harvest index increased with increased seed pieces and showed a linear relationship with sizes of planting material. The possible reason for increasing harvest index with increased sett size, it would be obvious that the success of the crop depends on the careful selection of planting material (Hartmann et al. 2002). Optimally bigger sized planting material was helpful in supply of adequate food reserves that ensure steady and rapidly increasing during the subsequent growth period of plant population and in turn enabled the plant to use effectively the available soil nutrients, moisture and other growth promoting factors properly to have good stand and produce more yield. Finally, Rashid et al. (2007) reported that concerning major crops the more the economical yield as made higher the harvest index of the crop plants. Therefore, increasing in harvest index with increase in sett size might be due to using the appropriate sett size, ability of sett sizes to use efficiently their leaf area index value for its economically important components (rhizome fingers, rhizome width and length). This is supported by significant and positive correlation between LAI and harvest index ($r = 0.65$, $P < 0.001$) (Appendix 6). All interaction effects were not significant ($P < 0.05$).

4. SUMMARY AND CONCLUSION

Ginger (*Zingiber officinale* Rosc L.) is highly adapted and the leading spice crop in southern Ethiopia, especially in Wolaita and Kambata-Tambaro Zones in both production and economic benefits. Its wide range of utilization in cultural foods and drinks in addition to its medicinal use makes the crop more valuable. However, the yield of ginger in Ethiopia is still very low. This is due to many production constraints such as less attention for optimal plant population per unit area (spacing) and using improper sett size are few of the many that impede to secure high yield.

A field experiment was carried out to determine the effects of three inter row spacings (20 cm, 30 cm and 40 cm), three intra-row (5 cm, 10 cm and 15 cm) spacings and three levels of ginger rhizome sett size (≤ 3 cm or 12.13 g, 3 - 6 cm or 27.4 g and 6.1 – 9 cm or 34.13 g) during 2008 cropping season at Areka, southern Ethiopia.

The results showed that in general plants attained higher canopy establishment and reached maximum growth between 120 and 165 days after planting and thereafter declined due to senescence. Inter row spacing had significantly (P <0.05) affected the number of tillers per plant, leaf width, Leaf area, leaf area index at 195 DAP, and it had significant (P <0.05) effect on rhizome length/plant, rhizome width/plant, rhizome fingers/plant, rhizome fresh weight ha^{-1} and HI. However, it had non significant effect on date to 50 % ginger emergence and on date to 90 % ginger maturity, plant height, number of leaves per plant and on average leaf length at 195 DAP.

Variation in intra-row spacing had a marked influence up on most parameters in the study. The growth and yield parameters which were significantly (P <0.05) affected by intra-row spacing were tillers per plant, plant height, leaf number per plant, shoot dry weight, leaf area and on LAI at 195 DAP and also rhizome length, rhizome fingers and total biomass. But intra-row spacing had no significant (P <0.05) effect on date to 50% of crop emergence, on date to 90% maturity, fresh rhizome yield per hectare, rhizome dry weight per hectare and harvest index.

The results revealed that sett size had significantly (P <0.05) affected date to 50% of crop emergence, date to 90% maturity, number of tillers per plant, plant height, leaf length, shoot dry weight, leaf area, shoot dry weight per plant, rhizome fresh weight ha^{-1}, total biomass, rhizome length/plant, rhizome width/plant, rhizome fingers/ plant, and harvest index. Increasing the rhizome sett size had significantly and positively affected all the above parameters, all the parameters increased with increased in rhizome sett size except leaf length. The findings showed that growth, yield and yield components of ginger can be influenced significantly by manipulating the size of seed pieces. Plants also attained maximum canopy establishment in all growth parameters during the165 DAP and thereafter vegetative growth start to decline.

One the other hand, the interaction effect of inter row x intra-row spacing was found to be significant on shoot dry weight at 165, similarly, inter row spacing x sett size was showed significant on both total biomass and rhizome dry weight per hectare. The maximum shoot dry weight (30.4 g per plant) from 40 cm x10 cm at 165 DAP; the maximum rhizome dried yield (13543 $kgha^{-1}$) was obtained from the interaction of 20 x 15 cm inter and intra-row spacings, respectively, and this can be recommended for dry yield production.

In this study, the highest fresh rhizome yield (41808 kg ha^{-1}) was achieved at largest sett size (6.1 - 9.0 cm) irrespective of the inter row spacing and intra-row spacing. The size is also similar with the recommendation of Tepi and it can be recommended for the study area irrespective of inter row spacing and intra-row spacing. Next to sett size, it was observed that both the narrow and medium inter row spacings (20 and 30 cm) produced significantly higher fresh rhizome yield as compared to wider (40 cm) inter row spacing. The maximum yield per hectare (36429.6 $kgha^{-1}$) was obtained at the narrow inter row spacing (20 cm), though it did not significantly differ from the yield obtained from the 30 cm (34267.2 $kgha^{-1}$) inter row spacing. Similarly, intra-row spacing resulted in non significant variation in rhizome fresh yield, among the three levels (5, 10 and 15 cm).

In general, the narrow inter row spacing (20 cm) had higher rhizome yield per hectare than 30 cm spacing and 10 cm intra-row spacing produced higher than the yield obtained from 15 cm intra-row spacing. However, the variation between these two inter (20 and 30 cm) and three intra-row spacings were non significant. On the other hand, the fresh yield - crop densities was explained by the linear function but the difference in yield is comparatively small to the yield expected to compensate for higher seed cost and labor cost involved for additional densities. Moreover of that, the most densely populated plant had management problems, the yield in the soil also intermingled to each other, and though, the market value can also be decreased. As a result of these factors, it seem better instead of using inter row spacing 20 cm x 10cm intra-row spacing (500000 plants per hectare) or 30cm x15cm inter and intra-rows (222222 plants per hectare), it is preferable to use 30 cm x 10 cm inter and intra-row spacing or 20 cm x 15 cm intra-row spacing (333333 plants per hectare). Since the results are based on one season data, it will be necessary to undertaken more experiments to confirm the consistency of the results.

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