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Effects of Clove Size and Plant Density on the Bulb Yield and Yield Components of Garlic (Allium sativum L.) in Sodo Zuria Woreda, Southern Wolaita Zone

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Abstract
A field experiment was conducted during the 2014/15 cropping season near Sodo town at a site called Marchare/Kokate Kebele Sodo Zuria Woreda, Wolaita Zone of SNNPRS, to evaluate the effects of clove size and plant density on the clove yield and yield components of garlic (Allium sativum L.). Treatments comprised of three clove sizes levels (1.0-1.49, 1.5-1.99 and 2.0-2.50g) and three plant spacing levels (5 cm, 7.5 cm and 10 cm) which were laid out in factorial arrangement in randomized complete block design with three replications. Tsedaye TT1 variety from Debre Zeit Agricultural Research Center was used for the experiment. Data were collected on plant height, leaf number, leaf length, small clove sizes, medium clove sizes and large clove sizes, marketable and unmarketable and total yield (t/ha) The result revealed that the main effects of clove sizes and plant spacing had significant effects on plant height, leaf number, mean clove weight and diameter, total yield, total marketable and unmarketable number. There was no statistical difference ($p<0.05$) on no clove or bulb, clove dry matter, leaf length leaf width, shaft diameter dry matter content due to treatments. The result showed that interaction of clove size level and plant spacing was not significantly ($p<0.01$) influenced in all parameters. Specifically, both marketable and total yields showed increasing trend with increase in nitrogen rates where the highest total marketable yield (289.94 t ha^{-1}) and total yield (262.22 t ha^{-1}) were recorded at the level of 289.94g $ha^{-1}$and plant spacing 10cm which was 262.22(t/ha) obtained Regarding the wide plant spacing 10cm, extended days to physiological maturity was recorded with clove sizes level up to 7.5cm. The results of the experiment suggested that the garlic variety Tsedaye responded well to the levels of clove sizes and plant spacing .In conclusion, using of clove sizes 2.0-2.50g and plant spacing of 10cm cm was found to be promising for yield of garlic.
Keywords: Clove, Plant Density, Bulb Yield, Yield Components and Garlic

1. INTRODUCTION

Garlic (*Allium sativum*L.) is the second most important *Allium* species next to common onion (*Allium cepa* L.) (Jones and Brewster, 1994). It is grown worldwide in all temperate to sub-tropical areas as an important spice and medicinal plant (Fritsch and Friesen, 2002).

Garlic is primarily grown for its cloves used mostly as a food-flavouring condiment. Green tops are eaten fresh and or cooked. In tropical areas consumption of immature bulbs for salad use is also popular (Purseglove, 1975; Dupriez and De Leener, 1989; Rice *et al*., 1990; Rubatzky and Yamaguchi, 1997; Fritsch and Friesen, 2002). Garlic is one of the best-studied medicinal plants that its antibacterial and antiseptic property is well known. The use of garlic was well documented by the Egyptians, Greeks and Romans. Garlic contains remedies, which were applied against heart problems, headache, bites, worms and tumours (Keusgen, 2002) and as a herbal remedy reduces a multitude of risk factors which play a decisive role in the genesis and progression of arteriosclerosis (Brewster, 1994; Rubatzky and Yamaguchi, 1997; Siegel *et al.,* 2000). Brewster (1994) reported that many actions associated with garlic supplements may help prevent or potentially alleviate arteriosclerosis (inhibit the aggregation of human blood platelets to form the clots which have the potential for arterial blocking which narrow arteries). Garlic has been demonstrated to kill parasites including amoeba and hookworm in test tubes and animals (www. health notes. com, 2002). Garlic's active constituents have also been shown to kill hiv in the test tube, though these results have not been confirmed in human trials (www. health notes. com, 2002). In one study, administration of an aged garlic extract reduced the number of infections and relieved diarrhoea in a group of patients with aids (www. Virtual healthily, 1998).

The world garlic cultivation was increased from 771,000 ha (hectare) in 1989-91 to 1,126,000 ha of land in 2002 with total production of 6.5 million and 12.1 million tons respectively. The major producing countries are China, India and Korea Republic (FAO, 2003). In Ethiopia the *Alliums* group (onion, garlic, leek and shallot) are important bulb crops produced by small and commercial growers for both local use and export (Yohannes, 1987; Metasebia and Shimelis, 1998).

In Sodo Zuria Woreda, garlic is produced in the highlands and mid altitudes both for home consumption and for local market as a source of cash (Alemu, 1998). The production activities are carried using local cultivars and planting is done in closer spacing with or without addition of organic fertilizer. The size of cloves used varies because planting is done on the available clove size at hand. Farmers are not well aware of the different agronomic practices influencing yield. The use of inappropriate clove size and planting density could reduce yield considerably.

There is shortage of information on specified planting density for different clove weight (size) of the crop in Ethiopia that can greatly help to increase garlic production. Considering the importance of garlic as one of the potential vegetable crops for both domestic consumption and export, it is imperative to increase its productivity along with appropriate planting size and plant density. Therefore, there is need to identify the optimum planting size and plant spacing) for optimum bulb yield and quality. The present study was proposed for the following objective:

- To identify the optimum clove size and intra-row spacing for optimum yield and quality of garlic.

3. MATERIALS AND METHODS

3.1. Description of the Study Area

The experiment was conducted at Sodo Zuria Woreda, in Marachare/ Kokate Kebele, Wolaita Zone Southern Nations Nationalities and Peoples Regional State during the cropping season of 2015. Which is located 329 km south west of Addis Ababa, 156 km south west of Awassa? The site is located at 34° 21' E longitude and 4° 27' N latitude. The area has an average annual rainfall range of 1252 mm with the main growing season (August-October) 639mm and average minimum and maximum temperatures of 13.5^{0}C and 23 ^{0}C, respectively. It is also situated at an altitude of 2190 meters above sea level (BOARD, 2008 and Dawit, 2010).

3.2. Experimental Materials and Cultural Practices

Tsedaye variety, which was selected from Debre Zeit Agricultural Research Center and stored with dry tops attached for about four months, will prepared for planting. At planting time, cloves were separated from the bulbs and sorted and graded according to their size category large (2.0-2.5 g), medium (1.5-1.9 g) and small (1.0-1.49 g). Land preparation was started in April 2015 and ploughed three times.

3.3. Experimental Design

The experiment was arranged in a RCB design with 3 replications following the procedures by Gomez and Gomez (1984). Plant spacing (5, 7.5 and 10 cm) was arranged as the main plots while the combinations of three levels of cloves size (large, medium and small) was assigned in the sub plots. There are a total of 27 treatment combinations. Each plot was 3 m long and the width varied according to the spacing between main plots and between replications was one and a half metre and two metres, respectively. The harvesting was done from the two central rows. The main plot treatments were first randomly assigned to the main plots followed by a random assignment of the sub plots treatments within each main plot.

3.4. Data to be collected

Data was collected from 5 randomly taken plants from two central rows. the yield of plants obtained from the two central rows of each replication at physiological maturity was determined for bulb yield per plot or yield (t/ha) separately after curing of the bulbs. Data was recorded for the following parameters: plant height, leaf length, leaf width, leaf number, bulb weight, bulb weight, clove weight category, clove weight, unmarketable and marketable clove category

3.5. Statistical Procedures

The data collected were subjected to analysis of variance for RCB design as per Gomez and Gomez (1984) and least significant difference (LSD) was used to separate the means at 0.01 and 0.05 probability levels using SAS software computer version 9.1

4. RESULTS AND DISCUSSION

4.1. Clove Size and Plant Spacing on Growth of Garlic

Plant spacing and Clove size did significantly affect plant height and leaf number. However, Clove size and plant spacing did not significantly affect leaf length and leaf width and also, the wider the planting spacing the higher was the leaf number in (Table 1 and Appendix Table 1). This result is in agreement with the findings of Om and Srivastava (1977) on garlic. Singh and Sachan (1999) also reported on onion that the greatest number of leaves per plant was found in the widest row spacing. This could be partly due to the fact that wider spaced plants produce more axillary branching than plants spaced at closer spacing's that resulted in higher leaf number per plant. Although leaf length was not significantly affected by all of the factors leaf length showed increasing trend as row and plant spacing decreased with increased size of cloves. The highest leaf length was recorded from 20 cm row spacing and 5 cm plant spacing with large-sized cloves planted treatments. This might be attributed to a competition effect for light at closer spacing. Large-sized cloves also competed and efficiently utilized growth resources for emerging shoots which gave the tallest leaf as compared to small-sized cloves.

Tabl 1. Effect of clove size and Plant Spacing on Plant height, Leaf length, leaf width and Number of Leaves of garlic

Treatments		Plant height (cm)	Leaf length (cm)	Leaf width (cm)	Leaf number
Factors	Levels				
Clove size	1.0-1.49 g	41.43bcd	36.06	1.22	5.02
	1.5-1.99 g	64.00ab	37.06	1.20	5.03
	2.0-2.50 g	79.96a	33.53	1.23	5.05
	LSD (0.05)	12.11	NS	NS	NS
Plant spacing	5 cm	72.40ab	49.63	1.33	11.20ab
	7.5 cm	73.59bcd	47.00	1.32	12.13ab
	10 cm	83.00a	49.60	1.30	12.43a
	LSD (0.05)	12.07	NS	NS	2.32
CV (%)		11.18	28.77	4.46	13.85

NS=Means not significantly different at 5% probability level.

4.2. Effects of Clove Size and Plant Spacing on Yield and Yield Components

Differences in yield (t/ha) were significantly higher both for clove size and plant spacing ($P < 0.01$) (Table 4 and Appendix Table 2). Large-sized garlic cloves significantly out yielded than the small-sized seed cloves. This finding was in agreement with the results of Lemma and Herath (1994) on the effects of size of onion sets on bulb yield. The size of planting stock has influence on the final bulb size in that bulbs tend to increase with increasing clove size planted (Jones and Brewster, 1994). This could be attributed to the fact that large-sized cloves have relatively more reserve food for emerging shoot to utilize and rapidly establish itself and efficiently utilize resources during the growing season compared to small-sized cloves with relatively less reserve food.

Plant spacing of 10 cm also resulted in highly significant ($P<0.01$) yield increase over the spacing of 7.5 and 5 cm between plants. There were no significant yield differences between the different planting spacing. The differences in total yield as a result of decreased population densities, however, were observed to be compensated for, at least in part, by an increase in yield of over-sized cloves and a decrease in small-sized ones. The highest yield at high plant density levels may be attributed to the over compensatory effect of number of plants per unit area. However, it gave lower yield per plant due to reduction in size of individual cloves as a result of increased competition for light and nutrients.

Plots planted with small-sized seed cloves produced significantly more ($P<0.01$) number of very small-sized cloves but produced significantly lower ($P<0.01$) number of cloves in the medium and very large-sized clove categories. In contrast to this, plots planted with large-sized seed cloves resulted in significantly fewer number ($P<0.01$) of the very small clove and more number of the medium and very large-sized clove categories. Similarly, size of planting material showed significant effect on yield distribution by all clove size categories. Plots planted with small- sized seed cloves gave significantly higher ($P <0.05$) yield of the very small-sized cloves compared to those planted with large and medium-sized seed cloves. Plots planted with both large and medium-sized seed cloves gave significantly higher ($P<0.05$) amount of small and large-sized clove categories and highly significant ($P < 0.01$) yield of medium and very large-sized cloves (Table 4).

Planting large and medium-sized seed cloves did not show significant differences in the yield of all clove size categories. Except in the small-sized clove category, where clove size showed highly significant ($P< 0.01$) increase at 10 cm plant spacing, the other plant spacing treatments did not show significant increase in the yield of the different clove size categories. However, with increase in plant spacing from 5 to 10 cm a decreasing trend in number and size of cloves in the very small size category and increasing trend in the other clove size categories were observed.

Clove size and clove number were higher with cloves planted at the widest spacings. Similarly, Lawanda. *et al*. (1994) found in garlic that with widening plant spacing the size of bulb, weight of bulb and number of cloves per bulb gradually increased. They further indicated that wider spacing favoured better development of bulbs

Table 2. Effects of plant spacing and clove size on yield and clove size distribution of garlic

Treatments		Yield	Small clove		Medium clove		Large clove	
Factor	Levels	(T/ha)	(No)	(g)	(No)	(g)	(No)	(g)
Clove size	1.0-1.49 g	15.98	43.5	53.0	25.0	43.3	20.0	45.0
	1.5-1.99 g	17.16	48.8	63.1	28.2	50.9	23.7	54.3
	2-2.50 g	17.99	51.1	65.6	32.7	58.7	24.3	56.8
	LSD	1.54**	NS	8.8*	6.2**	10.9**	NS	9.1*
Plant spacing	5 cm	18.35	43.3	56.4	25.8	46.6	21.4	49.4
	7.5 cm	16.78	44.8	56.5	29.1	51.8	22.1	50.6
	10 cm	16.00	55.3	68.7	31.0	54.5	24.6	56.1
	LSD	1.54**	9.30**	8.80**	NS	NS	NS	NS
CV (%)		12.4	26.7	26.5	29.6	29.2	33.0	31.9

NS, *, **Indicate -non significant and significant differences at the 5% and 1% probability levels, respectively

Total bulb weight (TBW), mean bulb weight per plant (MBW), and mean clove weight (MCW) were significantly different (P < 0.01) for the different clove sizes planted (Table 5 and Appendix Table 3). Large and medium-sized seed cloves planted plots were superior to the small clove weight planted plots in the total bulb weight, mean bulb weight and clove weight. Although the highest total bulb weight was obtained from large-sized seed cloves, the differences from plots planted with medium-sized cloves were not statistically significant.

The mean clove weight from both plots planted with large and medium-sized cloves was significantly higher than those planted with small-sized cloves. Mean bulb weight per plant, mean clove weight and clove number per bulb. Similarly, size of cloves planted did not affect the number of cloves per bulb. Plant spacing did not show significant differences in mean clove weight and clove number per bulb. The result observed in this study agreed with the work of Brewster (1994) on garlic and Lemma and Herath (1994) and Geleta*et al. (*1995) on onion. Their findings showed that yields were highest from the large-sized seed cloves/bulbs and lowest from the small-sized seed cloves /bulbs used for planting. This is possibly due to the fact that larger-sized seed cloves produced greater amounts of marketable cloves than the cloves obtained from smaller-sized seed cloves. However, the results obtained in this study contrast with those obtained by Ali (1994) on garlic crop in that large (2.0 g), medium (1.1 g) and small (0.5 g) sized seed cloves did not show significant differences in either yield or average bulb weight.

Yield per plant was significantly (P<0.05) decreased as plant density was increased. In general, yield showed a decreasing trend with increase in the row and between plant spacings. This reduction in yield with increased row width and plant spacing is consistent with the results of Bleasdale (1966) and Frappell (1973) on onion as well as with report of Om and Srivastava (1977), Minard (1978) and Castillo *et al.* (1996) on garlic. This could be attributed to the fact that plots at higher plant densities were atintense competition for growth resources as a result it gave less yield per plant as compared to plots with less plant densities, where resources were not limited to support better growth and partitioning of assimilates. Total bulb weight and mean bulb weight were also significantly affected by plant spacing, where 10 cm plant spacing gave a highly significant total bulb weight and mean bulb weight over the 5 cm plant spacing treatments. Total bulb weight and mean bulb weight of 5 cm plant spacing were not significantly different from 7.5 cm plant spacing.

Table 3. Effects of clove size and plant spacing on total marketable yield, total Unmarketable yield and clove weight, clove number and bulb dry matter of garlic

Treatments		TMY (g)	TMT/p (g)	MCW (g)	C No /bulb	BDM (%)
Factors	Levels					
Clove size	1.0-1.49 g	242.26	16.30	1.15	13.10	31.76
	1.5-1.99 g	276.57	18.44	1.36	12.74	30.96
	2.0-2.50 g	289.94	19.33	1.48	12.22	31.74
	LSD	19.98**	1.40**	0.14**	NS	NS
Plant spacing	5 cm	242.30	17.29	1.33	12.38	33.10
	7.5 cm	244.26	17.57	1.35	12.39	32.10
	10 cm	262.22	18.62	1.32	13.29	32.26
	LSD (0.05)	13.98*	1.05*	NS	NS	NS
CV (%)		10.15	10.66	14.28	11.43	6.28

NS, *, ** Indicate non-significant and significant differences at the 5% and 1% probability levels, respectively.

At low plant population where competition for light and other resources is low, mean bulb yield per plant and mean clove weight were higher as compared to higher plant population (Frappel, 1973; Rogers, 1977; Brewster and Rabinowitch, 1990 and Nourai, 1994). But as plant population increased competition appeared to be more important which led to lower bulb weight and mean clove weight. Plots planted with large-sized clove gave higher total bulb weight implying the availability of large amounts of assimilates that could be used for partition to produce total large bulbs. However, lower total bulb weight from small-sized clove planted plot indicated that assimilates for bulb formations were not sufficient to produce large bulbs.

The plant spacing and clove size treatments significantly affected the dry matter content of garlic bulbs (**Table 5 and Appendix Table 3**). However, increasing trend in the contents of dry matter was observed as plant density increased. This result was found to be similar to the result of Lazic (1975) where he indicated that using big sets increased the yield of onion without affecting the content of dry matter. Yeshi (2003) also reported that the shallot bulb dry matter content was not significantly different among different bulb sizes obtained by N fertilization and by the interaction of bulb size used for planting and N fertilization. This is possibly due tothe higher amount ofwater content inlarger bulbs as compared to smaller ones. As a result, bulbs that have different sizes gave a non-significant dry matter content.

4.5. Influence of Clove Size, Plant Spacing and their Interactions on the Marketable and Unmarketable Clove Sizes

There are no grade standards for garlic crop in Ethiopia. Nevertheless, from experience itcan beargued that size grade category is more of specific attribute for a cultivar. In this study the size category based on marketable and unmarketable were explained as follows.

4.5.1. Marketable clove size (MC,≥2.0 g)

The size of planting material significantly affected marketable clove size both in the large and very large clove size category (Table 4, Appendix Table 2 and Appendix Fig. F). Large and medium-sized seed clove planted plots produced significantly ($p < 0.05$ and < 0.01 respectively) the highest marketable clove size. Both row and plant spacing did not show significant differences; however, consistence trend in increasing marketable clove size was observed as row and plant spacing increased. Frappell (1973), Rogers (1977) and Hatridge and Bennett (1980) also reported that, as plant density increased, there was a progressive shift of the modal-size grade to smaller grades. Generally, in all the clove size categories planting large and medium-sized seed cloves produced higher weight of marketable cloves than planting small-sized seed cloves.

4.5.2. Marketable clove size (MC, 1.5-1.99 and 1.0-1.49 g)

The marketable clove size was significantly affected ($P<0.01$) by the size of seed cloves planted (Table 4). Large-sized seed clove produced significantly ($P<0.01$) more yield of medium-sized cloves (58.7 g) compared with small-sized seed clove planted plots (43.3 g). However, the yield of marketable cloves with medium-sized clove planted plots did not differ significantly from the other clove sizes used for planting. This result was not in agreement with the findings of Yeshi (2003) on shallot, who showed acceptable bulb size was not significantly affected by the bulb sizes planted.

Clove size used for planting significantly ($P<0.05$) influenced the yield of cloves in the scarcely marketable clove size categories. Cloves obtained from treatments planted with large and medium-sized cloves produced more marketable clove (65.6 and 63.1 g, respectively). Small-sized seed cloves produced less marketable clove (53 g). These results were in agreement with those of Yeshi (2003) where small-sized bulbs of shallot produced few numbers of marketable bulbs compared to large bulb planted plots that produced greater number marketable size. Plant spacing at 10 cm resulted in a significantly higher yield of scarcely marketable cloves than 7.5 and 5 cm plant spacings (Table 4 and Appendix Table 2). Higher plant population resulted in higher total yields but also a greater number of unmarketable number of cloves.This may be attributed to less competition among plants for nutrients, moisture and light at 10 cm spacing which is responsible for the production and partitioning of assimilate to the cloves and production of greater weight of scarcely marketable cloves than the other two narrower plant spacings.

4.5.4. Unmarketable clove size (UMC, <1.0 g)

Plant spacing and clove size and their combinations did not significantly affect the unmarketable clove size. However, large-sized seed cloves planted plots produced significantly ($P < 0.05$) less amount ofunmarketable yield as compared to small-sized seed clove planted plots. Although not statistically different, the highest yield of unmarketable clove was obtained with row spacing 30 cm and plant spacing at 5 cm (Table 4 and Appendix Table 2).

Plots planted with Large-sized seed cloves produced less total yield of unmarketable clove size and unmarketable numbers of cloves as compared to plots planted with small-sized seed cloves. This seems to indicate that planting large-sized seed cloves does not necessary lead to the production of large number of marketable cloves. Lemma and Herath (1994) also noted that small sets of onion produced significantly less marketable and total yields. Similar results were not observed by Yeshi (2003) on shallot in which higher number of unmarketable bulb size was obtained in plots planted with large-sized bulbs and an increase in the bulb size of the planting material resulted in decreased production of marketable bulbs. The increase in the number of unmarketable cloves when small-sized seed cloves were used for planting could be attributed to failure of the small-sized seed cloves to develop plant to optimum size early in the growing season that perhaps reduced the amount of assimilates transferred to individual cloves before growth ceased and thereby making them very small.

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7. APPENDICES

Appendix Table 1. Mean square of garlic plant height, leaf length, width and number due to clove size, plant spacing and their Interactions

Source of variation	df	Plant height (cm)	Leaf length (cm)	Leaf width (cm)	Leaf number (cm)
Replications	2	323.372	110.685	0.035	2.933
Clove weight (B)	2	56.501	14.962	0.005	0.007
Plant spacing(C)	2	11.238	47.444	0.001	0.298
Error (b)	48	18.587	18.379	0.003	0.151

*, ** Indicate significant differences at the 5% and 1% probability levels, respectively.

Appendix Table 2. Mean square of yield and clove size distribution of garlic from fifteen randomly selected plants

Source of variation	df	Yield (T/ha)	Small clove		Medium clove		Large clove	
			(g)	(No)	(g)	(No)	(g)	(No)
Replications	2	27.15	354.6	159.1	65.9	22.1	1255.2	246.9
Plant SP(C)	2	38.58**	1334**	1157**	429.1	183.1	338.9	61.27
Error (b)	48	4.45	256.6	162.9	220.8	71.6	275.5	55.3

*, ** Indicate significant differences at the 5% and 1% probability levels, respectively

Appendix Table 3. Mean square of bulb and clove size clove number and bulb dry matter of garlic

Source of variation	Df	TBW (g)	MBW/P (g)	MCW (g)	CN/B (No)	DM (%)
Replications	2	1212.33	3.58	0.04	3.71	10.06
Plant spacing(C)	2	3256.04*	13.21*	0.01	7.40	7.83
Error (b)	48	749.45	3.69	0.04	2.45	4.16

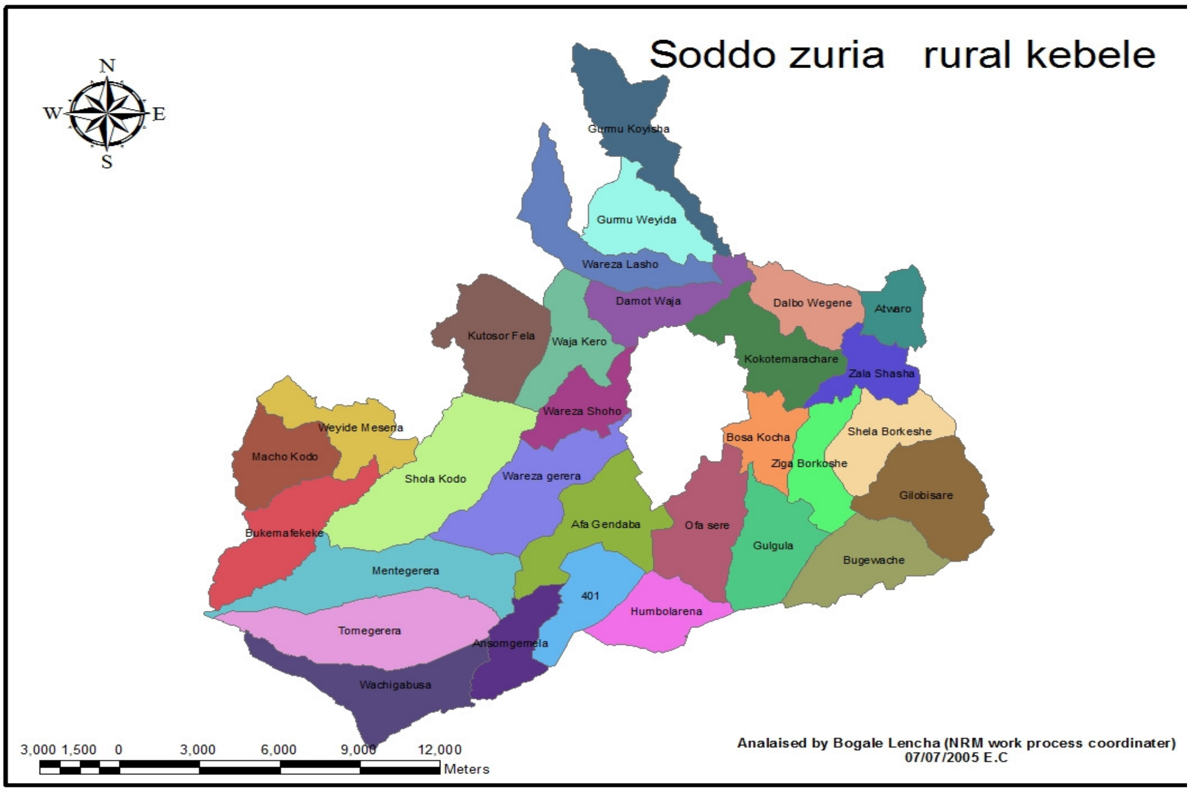
*, ** Indicate significant differences at the 5% and 1% probability levels, respectively

Abbreviations: TBW, total bulb weight; MBW/P, mean bulb weight per plant; MCW, mean clove weight; CN/B, clove number per bulb; DM, dry matter.

Appendix Table 4. Mean square of yield and yield components of garlic- clove length and width

Source of variation	df	Small clove (cm)		Medium clove (cm)		Large clove (cm)	
		Length	Width	Length	Width	Length	Width
Plant spacing(C)	2	0.12	0.02	0.15	0.01	0.17	0.01
Error (b)	48	0.07	0.01	0.08	0.01	0.08	0.02

*, **Indicate significant differences at the 5% and 1% probability levels, respectively.



Appendix Figure 1. Map of Woliata Zone by Woreda