EVALUATION OF THE EFFECT OF NPK FERTILIZER AND SPACING ON GROWTH AND YIELD OF GARLIC (ALLIUM SATIVUM) IN BOMET COUNTY

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ABSTRACT

Garlic, of soft neck variety with the silver skin cultivar was evaluated for growth and yields performance under different inorganic NPK (23: 23:0) fertilizer regimes and plant densities. The objectives of the study were to determine bulb yield of garlic grown on four different NPK (23:23:0) fertilizer regimes, to establish the effects planting density on garlic bulb yield and to determine the effects of NPK fertilizer and planting density on garlic yield. From the study it was concluded that spacing and fertilizer application influenced growth and yield of garlic and as such it is important to use appropriate fertilizer and plant density for enhanced garlic productivity among smallholder farmers in Bomet County for improved household incomes from this crop and hence poverty reduction.

Key Words: NPK, fertilizer, spacing, growth and yield, garlic

1.1 Background Information

In Kenya as well as in other East African countries, there is overdependence on maize as the main food crop with low consumption of vegetables which are important component of human diet (Asian Vegetable Research Development Centre for Africa *(*AVRDC), 2004). Although maize is Kenya's staple food, its average yield per hectare is among the lowest in the world and its annual production increase is around 1.9% compared with population growth rate of around 2.9% (Mwangi, 2005). This serves as an indicator to diversify on food production for improved food and nutritional security and household incomes. To address food and nutritional security as well as improved household incomes, farmers will need to include a wide range of both local and export vegetable species in cereals, tuber and livestock production systems that are critical in contributing to food, nutritional security and household incomes (Kamau, Githuku & Olwande, 2011).Vegetables are recognized source of essential nutrients that lacks in many diets, and their production is becoming a source of self-employment and income generation in rural areas leading to rural development and a source of foreign exchange in the country. Production of certain vegetables is getting more attention as they offer medicinal value. There has been an increase in emerging diseases especially lifestyle diseases whereby the conventional medicines has not been able to cure or prevent. Use of alternative preventive and curative measures especially medicinal vegetables has increasingly become important. As the rise in demand for medicinal vegetables has increased, this has opened up an opportunity for small scale farmers to increase their farm incomes by growing plants/vegetables with medicinal value (Zaweria, Jacob & Kishoshi, 2002). The Ministry of Agriculture (MOA) and the related ministries and institutions are guided by Agricultural sector development strategy (ASDS) 2010-2020 which emphasis on promotion of local and export vegetables but no specific policies for these crops especially the medicinal ones leading to poor attention on them especially research work and hence low production among the small scale farmers and limiting their commercialization

(Mburu & Wale, 2011). Farmers in Bomet County have been planting garlic for years but yields have continued to decline. According to the Ministry of Agriculture (2013), the average garlic yield in Bomet County stands at 4 tons per hectare compared to a potential of 10 to 12 tons per hectare (KARI, 2013). The low garlic yield is attributed to inferior cultural and agronomic practices accorded to the crop by farmers, as they do not use fertilizers in garlic and if any, it is insufficient compared to the recommended rates, coupled with the unconventional spacing used of garlic, with some farmers having exceptionally wide densities and others small densities between crops. Thus the study shall aim to examine the effect of different levels of NPK (23:23:0) fertilizer to yield of garlic planted in different plant densities.

1.2 Statement of the Problem

Although Bomet County is of medium agricultural potential, farmers are highly dependent on maize production giving little regard to other crops in which the county has a high potential and comparative advantage especially vegetable production. According to KARI (2013), garlic production in county stands at 4 tons per hectare, which is way below the potential production. Major causes of low garlic production have been associated with low fertilizer application or none at all, partly due to high costs of the fertilizer and farmers' insufficient technical know-how on fertilizer use and other recommended practices in vegetable production. Lack of sufficient funds and other constraints deter majority of farmers from using the inorganic fertilizers in recommended quantities and balanced proportions (Babatola & Olaniyi, 2011). Similarly, farmers employ varied spacing in garlic whereby some are too close giving raise to poor bulb formation, while other spacing are too wide giving rise to low plant population and hence low yields. Commercialization of garlic production can only be achieved if its productivity is increased with reasonable costs of production for higher returns to farmers. In view of these, the study was carried out to determine the appropriate levels of NPK fertilizer that could be applied within a given area to give better garlic yields in Bomet County.

1.3 Objectives of the Study

i. To determine effects of NPK fertilizer on bulb yield of garlic.

ii. To establish the effects of planting density on bulb yield of garlic

iii. To establish the effects of NPK fertilizer and planting density on bulb yield of garlic.

2.1 Literature Review

2.1.1 Garlic Origin and Geographical Distribution

Garlic is a species in the onion family Liliaceae, and is known to have been cultivated in South East and Central Asia as early as 2,000 B.C and is among the oldest known horticultural crops worldwide (Zaweria *et al.*, 2002). Some writings suggest that garlic was grown in China as far back as 4000 years ago. There are other plants locally referred to as "wild garlic", but these are invariably other species of the garlic genus (*Allium*) not garlic itself (*Allium sativum*). Garlic producers and consumers have come through 5000 years of history growing and eating the crop with little need to specify type or variety. In fact it is a rather modern habit of only the last few hundred years whereby more detailed descriptions of varieties have come to be developed for any crop plant (Etoh & Simon, 2006). According to FAO (2004), garlic is an important vegetable in the world with production reaching about three million metric tonnes per annum, with majority of production occurring in China, the United States of America, Egypt, Korea, Russia and India. In Kenya garlic is commonly grown in small-scale farms and the annual production average is about 2000 metric tons (FAO, 2004).

2.2 Garlic Varieties

There are two common types of garlic species, with the hard neck garlic; *Allium sativum*ophioscorodon is considered the more primitive type, producing a tall stalk with a cluster of bulbils and undeveloped flowers at the top (Fleischaurer & Poole, 1979). These bulbils stalks emerge curled and looped in a variety of ways. How the stalk is produced and emerges is one of the classification descriptors of the different types within the general "hard neck". Soft neck garlic's, *Alliumsativum,* do not produce a central stalk above the ground clusters of bulbs and are developed over millennia of selection from hard necks (Rosen, Becker, Fritz & Wright, 2008). Hard necks have better and more complex flavor than soft necks, while soft necks have better yield, storage and require less field maintenance making them garlics of choice. According to Zaweria *et al.* (2002*)*, both hard neck and soft neck do well in agro-ecological zones upper midlands (UMs) and lower highlands (LHs) but the common garlic type grown in Kenya is the soft neck.

2.3 Nutritive Value of Garlic

According to McGee (2004*)*, garlic contains valuable food ingredients which are essential for human body growth and maintenance. Garlic has very little saturated fat, cholesterol or sodium but it is a rich source of minerals and vitamins recommended in cholesterol and weight reduction programs. Jonnes & Goebel (2001) stated that garlic acts as a source of energy and provides calories of 1,490 kcal per kilogram. In their analysis, the same authors say that hundred grams of garlic contain 33 percent of carbohydrates, 6.3 percent of proteins, 0.5 percent of fats and over 100 percent of vitamins and minerals which include vitamin C and B-complex group like niacin, thiamine, pantothenic acid, riboflavin and foliate which are necessary for daily dietary requirements for human beings.

2.4 Medicinal Value of Garlic

For many years, garlic has been used in both food and medicine as far back as when the pyramids were being built in Egypt. In addition to its food flavoring characteristics, garlic has many medicinal benefits. Scientifically, the medicinal value of garlic is widely recognized, and is available in many forms as over-the-counter drugs that target blood conditions and also in anti-viral medication (Block, 2010). There are a number of compounds found in garlic, allicin which is both an antibiotic and antifungal compound (phytoncide). Studies conducted have shown that the said compounds are effective in offering relief to pain, deworming, and anti-bacterial infections. Garlic is rich in a variety of powerful sulfur-containing compounds including thiosulfates (of which the best known compound is allicin), sulfoxides (among which the best known compound is alliin), and dithiins (in which the most known compound is ajoene). While these compounds are responsible for garlic's characteristically pungent odor, they are also the source of many of its health-promoting effects (Lawson & Gardner, 2005). The use of herbs is a time-honored approach to strengthening the body and treating diseases.

2.5 Garlic Spacing and Plant Density

Generally, as the plant population increases, competition among plants for moisture, nutrients, light and carbon dioxide also increases. In low population, plants grow as isolated units for most of their early life and there is less interference with each other than in higher densities. The Kenya Agricultural Research Institute (KARI) recommends a spacing of 30cm between rows and 15 to 20cm between plants giving a plant population of 166,700 to 222,2000 plants per hectare. According to Zaweria *et al. (*2002*),* spacing garlic closely give raise to poor bulb formation and hence low yields, while too wider spacing give rise to low plant population and hence low yields. Optimum population level is the one which provides the plant with the best environment to express its capacity fully under the given conditions.

According to Purewal & Daragan (2004*)*, wider spacing increased number of leaves and plant height in garlic. The same authors argue that wider spread garlic showed increased performance in respect of yield components of individual plant, while close spacing resulted in higher yields per unit area. It is recommended that plants should be spaced in an appropriate manner to ensure maximum yields (Dayi, 2008)

2.6 Garlic Production

Garlic, *Allium Sativum* has a wide area of adaptation and cultivation throughout the world (Mohd, Desal & Parmar, 2011). It is suitable in medium to high altitudes of 500-2000 meters above sea level and temperatures of 30^0C are necessary for optimum bulb development but cooler temperatures in the early stages favors vegetative growth required for proper establishment (Zaweria *et al.*, 2002*)*. Garlic has good production potential on agro-ecological zone (AEZ) UM_1 and LH_{1-2} under rain fed conditions and UM_{2-3} and LH_3 under irrigation (KARI, 2013). It has been found that excessive rainfall coupled with humidity are detrimental to both the bulb formation and optimum growth for the crop, which occurs at temperatures of 12-24^0C. Zaweria *et al.* (2002*)* reported that garlic will grow under a wide variety of soils but for optimum performance, the crop requires deep fertile well drained light loams with lots of organic matter. KARI (2013) observes that clay soils should be avoided as malformed bulbs may result and the crop does well in soil pH of 5.5-6.8. Though it has been established that sexual propagation of is possible in garlic, nearly all planting is done asexually, by putting individual cloves in the soil (Salunke & Kadam, 1998). Deep cultivation of the field is necessary to ensure adequate rooting depth and the cloves are directly planted in raised beds or ridges at a depth of 2.5 cm and at a spacing of 30cm between the rows and 15-20cm between plants giving plant densities in range of 166,700 to 222,200 plants per hectare (Zaweria *et al., 2002*). According to KARI (2013), the seed clove requirement is about 500-700 kg/ha. With adequate moisture and temperature, roots emerge and leaves will sprout two weeks after planting and thereafter the crop undergoes a period of vegetative growth (Olivier, 1974). According to KARI (2013), the major garlic diseases in Kenya include onion yellow dwarf virus, which causes small bulbs and yellowing of leaves and various fungal diseases which include bulb white rot (*Sclerotiumcepivorum)* which attacks leaves and roots and can survive in the soil for ten years, downy mildew (*Peronospora destructor*), purple leaf blotch (*Botrytis allii*) caused by excess water, basal rot (*Fusariumoxysporum*), rust (*pacciniaalli)* which causes chlorotic spots and clove rot (*Penicilliumcorymbiferum*) a blue- green mold that infects stored bulbs as well as plants. Infected crops should be immediately treated either by removal or spraying with appropriate fungicides.

2.7 Benefits of using Fertilizer in Garlic Production

In any production process, the ultimate goal is the output *(*Kibaara *et al.*, 2008). In crop production yield is the most important output and both inorganic and organic fertilizers are yield boosters (Kang & Juo, 1979). Inorganic fertilizers are one of the major inputs in crop production, and its low fertilizer use is one of the factors explaining low agricultural productivity growth in Africa (Michael, Valerie, Kelly, Rono & Derek, 2007). According to Ministry of Agriculture (2012), to increase production and ensure food security and incomes at household level, the country would aim at increasing small-scale farms fertilizer consumption from the current 10 kg to 31 kg per acre by 2015. In every region of the world, intensification of crop-based agriculture has been associated with sharp increase in the use of chemical fertilizer (Babatola & Olaniyi, 2002). Given the low fertilizer use in Kenya, there can be little doubt that fertilizer use in Kenya must be increased if the country is to meet its agricultural growth targets, poverty reduction goals and environmental sustainability objectives. For this reason the country would require to implement programs that will spur growth in fertilizer use in ways that are technically efficient, economically rational and price stabilizing (Michael *et al.*, 2007). Application of fertilizer to crops is a necessary precondition for better yields and a quick method of achieving maximum productivity. Diagnostic methods to evaluate nutrient requirement of garlic showed that nitrogen is regarded as the nutrient that has the greatest influence on garlic yield and production by ensuring optimum leaf growth, root development and bulb formation (Mohd *et al., 2011*).

3.1 Research Design

3.1.1 Location of the study

The experiment was conducted in Bomet Agricultural Training Centre (ATC) in Bomet County during the short rains of November - December 2013 and stretching to long rains of March-May seasons of 2014. Bomet ATC is located 3 kilometers from the Bomet County Headquarters, and rises to about 1920 meters above sea level and is within agro-ecological zone (AEZ) lower highland two (LH_2).

3.1.2 Climatology

Rainfall in Bomet County within the LH_2 is well distributed except for small dry season in January and February. The rainfall can be classified into long and short rains. Long rains are from March-May but with low intensity while short rains are November-December with high intensity and this makes the main crops growing season in the area. The annual rainfall ranges between 1200-1500 mm per annum.

3.1.3 Soils

The soil types in the area are predominately chromo-lurid phaeozems partly lithic and rocky with mollicnitisols and are deep to moderately deep dark brown loams to smeary clay with humic top soil and generally well drained (Jaetzold *et al.*, 2011).

3.2 Experimental Procedure

Soil analysis was conducted to get an inventory of the available nutrients and other soil chemical factors for crop production. The top soil (0-20cm) had properties for the analyzed parameters as shown in table 3.1 below;

Soil Parameter	Analytical value	Class
pH	6.2	Medium acidic
Exch. Acidity me%	0.2	Adequate
Total Organic Carbon (%)	2.91	Adequate
Total Nitrogen (%)	0.14	Low
Phosphorous (ppm)	15	Low
Potassium (me %)	0.44	Adequate
Calcium (me %)	3.1	Adequate
Magnesium (me %)	2.41	Adequate
Manganese (me %)	0.84	Adequate
Copper(ppm)	1.42	Adequate
Iron(ppm)	223	Adequate
Zinc (ppm)	25.5	Adequate
Sodium (me %)	0.24	Adequate

The pH of the soil is suitable for garlic production as it is moderately above the critical value of 5.5 (KARI, 2013). Total organic carbon is adequately supplied in the soil. Available total Nitrogen and Phosphorous are inadequately supplied in the soil for garlic production, while exchangeable bases such as Potassium, Calcium and Magnesium are adequately supplied for garlic production.

The cloves for planting were soaked in water for 24 hours to trigger quick sprouting. The experiment was a two factor laid out in randomized complete block design (RCBD) with three replications. The treatments of the experiment were four NPK fertilizer levels (0, 90, 120 and 150kg/ha) applied to soft neck garlic variety-the silver skin type and three inter-row spacing (20, 30 and 40cm) all with one intra-row spacing of 20cm. Thus it was a 4x3 factorial experiment with 36 experimental units. The experimental unit plots were 2x2m each and separated by 1m path. Each block had twelve experimental units and was separated by 2m path from each other. For a spacing of 20x20 cm the plant population was 100 plants per the 4 m^2plot which translates to about 250,000 plants per hectare. For 30x20 cm and 40x20 cm the plant population per plot was 66 and 50 plants and the number of plants per hectare was 165,000 and 125,500 respectively. Five plants were randomly selected from the three central rows in each of the 12 experimental plots from which data on plant growth and yield contributing parameters was gathered and recorded for analysis.

3.3 Treatments and Treatment Combinations

The factors considered in the experiment were two; NPK (23:23:0) fertilizer levels and Garlic plant densities.

Treatments

(a) NPK (23:23:0) fertilizer levels

i. 0 kg NPK/ ha(F_0)

ii. 90 kg NPK/ha(F_1)

iii. 120 kg NPK/ha(F_2)

iv. 150 kg NPK/ha(F_3)

(b) Spacing levels

i. 20x20cm(**S_1**)

ii. 30x20 cm (**S_2**)

iii. 40x20 cm **(**S_3)

Treatment Combinations

The treatments were of 12 treatment combinations of the fertilizer levels and spacing.

Factors		Fertilizer level			
		F_0	F_1	F_2	F_3
Spacing	S_1	S_IF_0	S_1F_1	S_1F_2	S_1F_3
	S_2	S_2F_0	S_2F_1	S_2F_2	S_2F_2
	S_3	S_3F_0	S_3F_1	S_3F_2	S_3F_3

Key:

S1F0- Combination of spacing 20x20cm with zero NPK fertilizer level

S1F1- Spacing of 20x20cm with NPK fertilizer level of 90kg/ha

S1F2-Spacing of 20x20cm with NPK fertilizer level of 120kg/ha

S1F3- Spacing of 20x20cm with NPK fertilizer level of 150kg/ha

S2F0- Spacing of 30x20cm with zero NPK fertilizer level

S2F1- Spacing of 30x20cm with NPK fertilizer level of 90kg/ha

S2F2- Spacing of 30x20cm with NPK fertilizer level of 120kg/ha

S2F3- Spacing of 30x20cm with NPK fertilizer level of 150kg/ha

S3F0- Spacing of 40x20cm with zero NPK fertilizer level

S3F1-Spacing of 40x20cm with NPK fertilizer level of 90kg/ha

S3F2-Spacing of 40x20cm with NPK fertilizer level of 120kg/ha

S3F3- Spacing of 40x20cm with NPK fertilizer level of 150kg/ha

3.4 Plot Layout

The treatment combinations were recorded on twelve separate pieces of papers and randomized using simple random method and put in plots in a block. The plot size was 2m x2m with each block having 12 plots and replicated three times giving a total number of 36 experimental units in three blocks. The blocks were separated by a 2 m path and the experimental plots were separated by 1 m path.

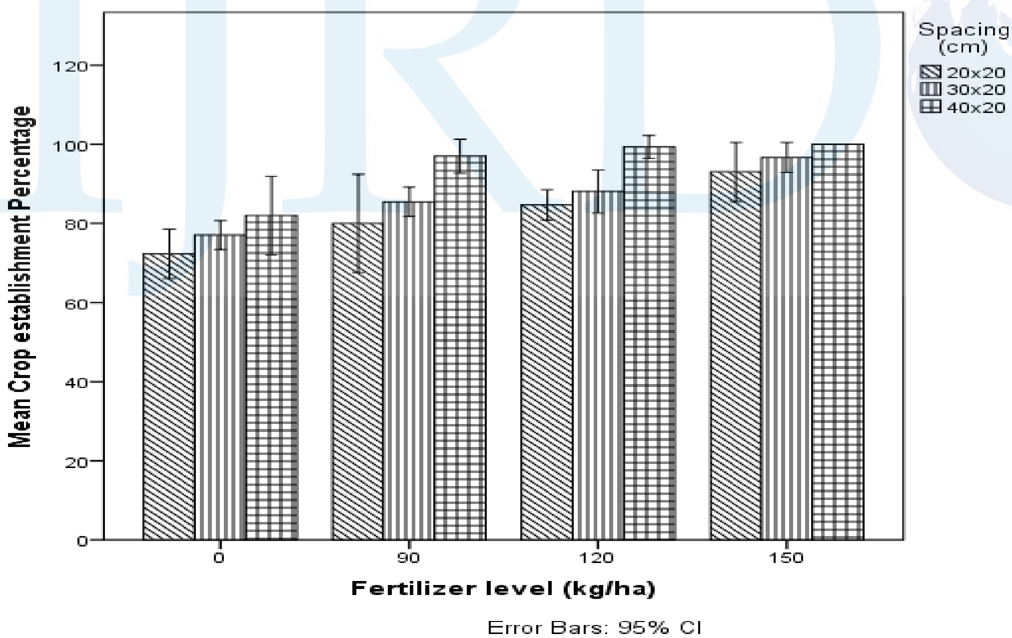
3.5 Data Collection and Analysis

Five plants from each of the 12 experimental plots were randomly selected from the three central rows of the plots and tagged for data collection. Observations and measurements on selected growth and yield parameters at various growth stages in response to the applied fertilizer and spacing were taken as follows; Crop establishment, Plant height, Number of leaves per plant, Number of plants with formed, Bulb diameter at harvest, Number of cloves per bulb, Fresh weight of bulb per plant at harvest, Total fresh plants weight per plot at harvest, and Yield of fresh bulbs per plot at harvest. The collected data was summarized using MS excel and then analyzed using statistical package for social scientists (SPSS) version 24. Analysis of variance (ANOVA) at $\alpha= 0.05$ level of confidence was conducted to determine if there were significant differences ($p< 0.05$) between the treatment means. Where the ANOVA indicated that there were some significant differences ($p<0.05$), post hoc test was conducted using Least Significance Difference (LSD) to determine where the differences existed.

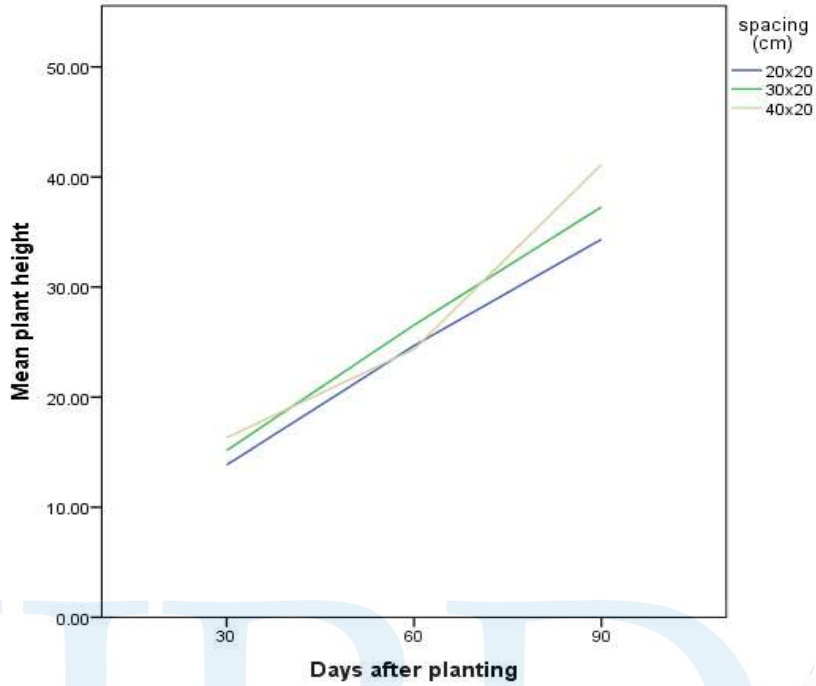
4.1 Results

4.1.1 Crop Establishment

From the figure below, it was observed that plots with fertilizer application had a better crop establishment as compared to the plots without fertilizer within similar spacing The results also showed that treatment with high fertilizer level and wider spacing reached 100 percent crop count in the 14th day while the other treatments had not reached 100 percent count with the lowest germination percentage being found in those plots with zero fertilizer application. The germination percentages for the other treatments except for treatment with 150kg/ha fertilizer level and 40x20 cm spacing were contrary findings by Zaweria *et al. (*2002) who stated the recommended period for garlic germination is 14 days after planting.

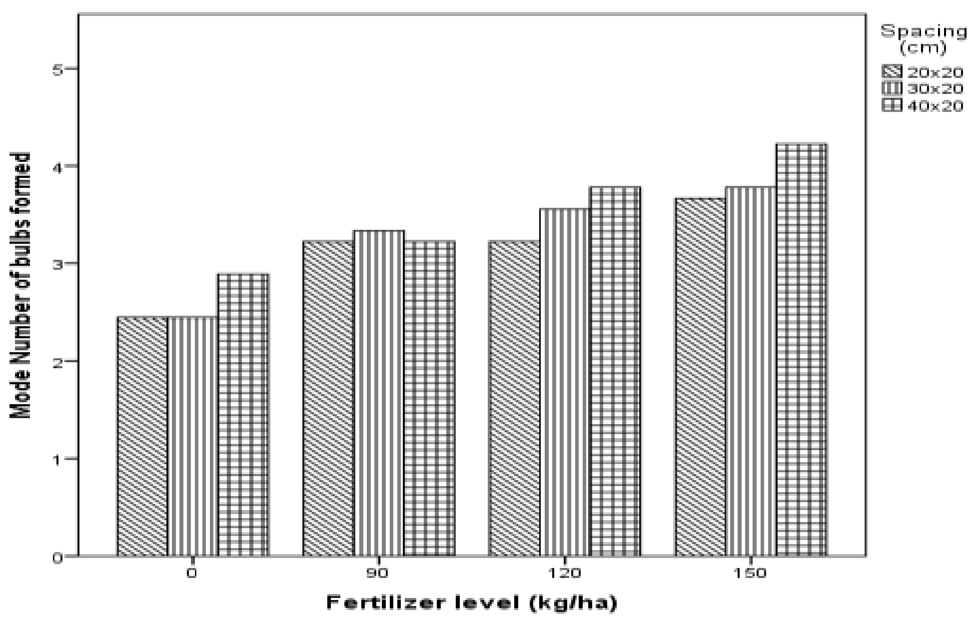


4.1.2 Plant Height



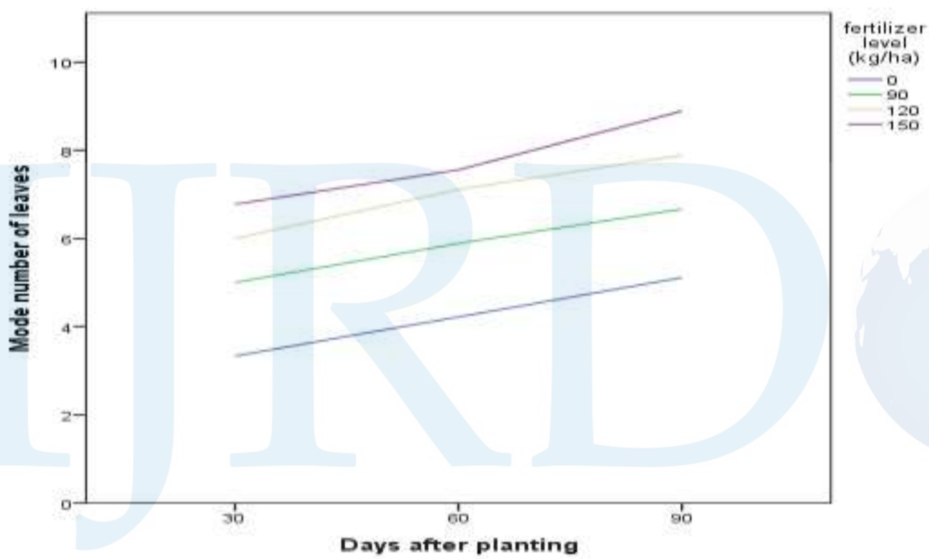
The above figure showed that mean plant height continued to increase with the number of days from planting. Wider spacing produced high mean plant height as compared to closer spacing. The highest plant height of 47cm was recorded in spacing 40x20 cm 90 days after planting

4.3 Bulb Formation per Plant



The results indicated that the number of plants with formed bulbs continued to increase with the days. Bulb formation per plant was significantly different among the treatments 30, 60 and 90 days after planting with regard to fertilizer level ($p<0.05$) but spacing as well as spacing and fertilizer interaction had no significant difference on bulb formation ($p>0.05$) during the 30,60 and 90 days after planting. Treatments with NPK showed higher mean bulb formation values compared to the plots with no fertilizer.

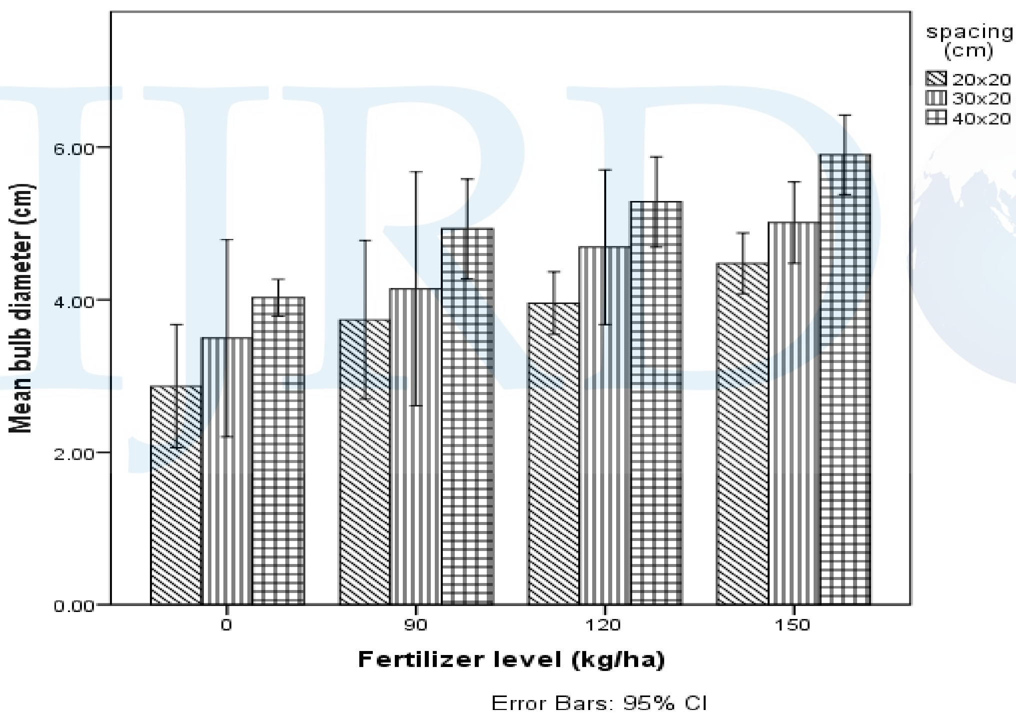
4.4 Number of Leaves per Plant



The leaves number increased with the number of days after planting within the treatments. The highest number of 9 leaves per plant was recorded in treatment with fertilizer level 150 kg/ha while the lowest mean leaf count of 5 was recorded in treatment with zero fertilizer application 90 days after planting. There was significant difference ($p<0.05$) among the treatments means on number of leaves with regard to spacing and fertilizer level at 30, 60 and 90 days after sowing. No statistically significant difference was observed on the number of leaves in the treatments ($p>0.05$) with reference to spacing and fertilizer level interaction only numerical differences existed.

4.5 Bulb Diameter per Plant

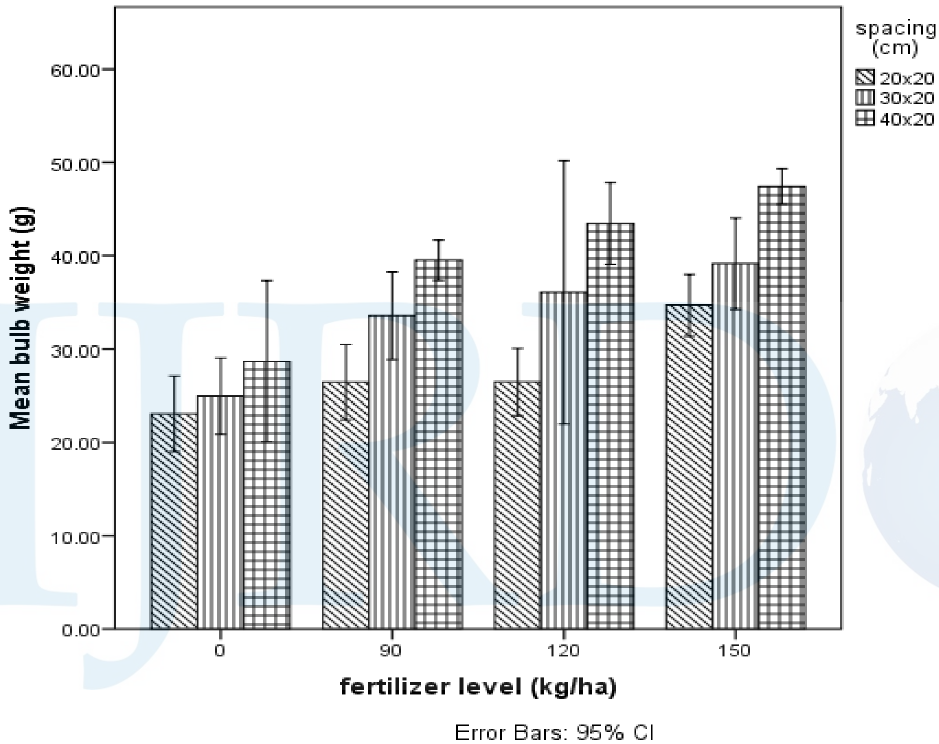
Mean bulb diameter increased with increase in spacing and fertilizer level with a maximum of 6 cm at spacing 40x20cm and fertilizer level 150kg per hectare and minimum of 2.5 cm at spacing 20x20 cm with zero fertilizer level as seen in the figure below. Fertilizer and spacing had significant influence on bulb diameter per plant at harvest ($p<0.05$) while interaction between fertilizer and spacing had no significant difference in mean diameter of garlic ($p>0.05$).



4.6 Fresh Bulb Weight per Plant at Harvest

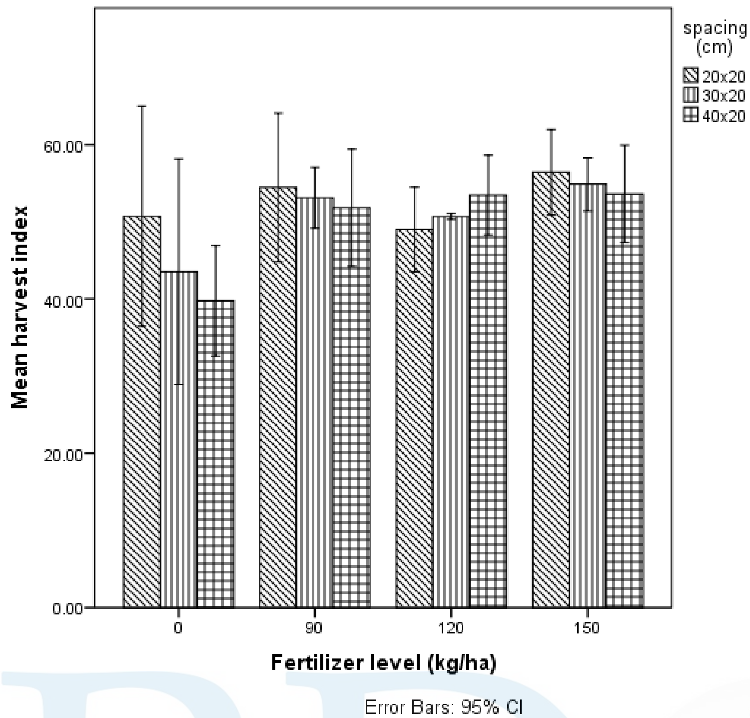
After harvest and having removed the soil from the root part, the stalk from each of the tagged plant from each experimental plot was cut off using a sharp knife and the individual bulb weighed using an electronic weighing scale. The highest mean fresh bulb weight of 47 grams per plant was observed in treatment with spacing 40x20 cm and fertilizer level of 150kg/ha while the minimum weight of 23 grams per bulb was recorded in treatment with spacing of 20 x 20 cm and zero fertilizer level as found in the figure below;

The results also showed that mean fresh bulb weight per plant increased with increase in spacing and increase in fertilizer level application. Spacing, fertilizer level and interaction between spacing and fertilizer had significant influence on bulb weight per plant ($p<0.05$).



4.7 Harvest Index

The harvest index was calculated as a proportion of the harvested bulbs to the total plant biomass. The highest mean crop harvest index was 58 while the lowest was 38 as observed in figure 4.11. Closer spacing with high fertilizer application seemed to produce higher mean harvest index.

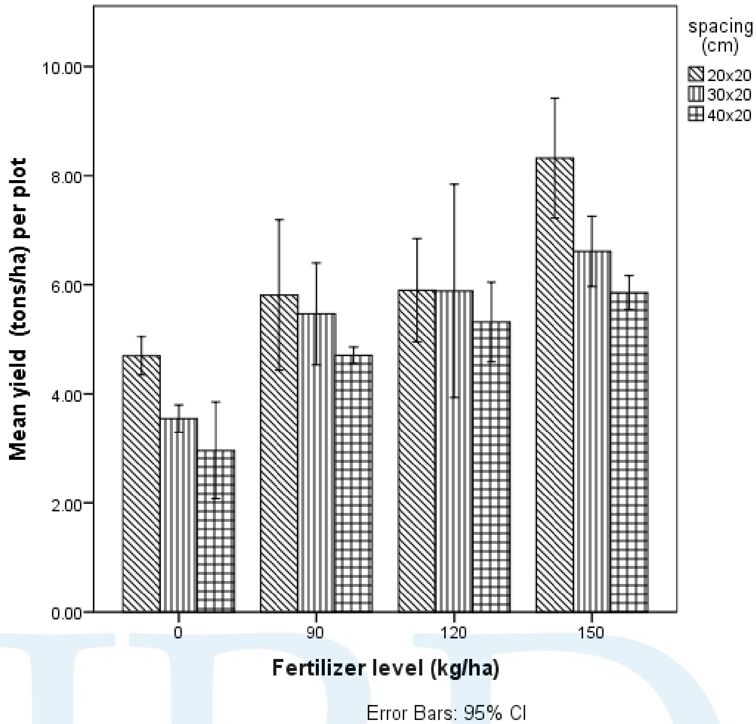


The spacing, fertilizer application level and interaction between fertilizer and spacing showed significant influence on garlic harvest index ($p<0.05$).

Spacing(cm)	20x20	30x20	40x20
20x20		2.1008	2.9867*
30x20	-2.1008		0.8858
40x20	-2.9867*	-0.8858	

4.8 Yield per Plot

The bulbs yields from the experimental plots were extrapolated to give yield in tons per hectare for all the treatment combinations. This was to help determine the spacing and fertilizer regime which gives highest yield.



The highest yield of 9 tons per hectare was obtained from spacing 20x20cm and fertilizer level 150 kg/ha while the lowest yield of 3tons per hectare was recorded in spacing 40x20cm and zero fertilizer level as shown in figure 4.11. Yield per plot seemed to increase with increase in fertilizer regime within same spacing. Those plots supplied with fertilizer showed higher yields as compared to control plots were no fertilizer was applied (Figure 4.11). Mean garlic yield in tons per hectare showed significant difference with respect to all spacing and fertilizer levels as well as spacing and fertilizer interaction ($p<0.05$).

5.1 Conclusion

Application of NPK fertilizer had significant influence on both garlic growth and yield parameters studied. Plots supplied with fertilizer showed higher mean values for the studied parameters as compared with plots where no fertilizer was applied. Spacing also showed significant influence on the growth and yield parameters studied. Wider spacing showed increased garlic performance in respect of yield components and yield of individual plant while closer spacing resulted in higher yield per unit area according to this study.

5.1 Recommendations

The following recommendations can be made from this study;

i. The results have showed positive response of the test garlic variety to NPK fertilizer application by increasing individual bulb weight and total bulb yield. It can therefore be recommended that NPK (23:23:0) fertilizer be incorporated as a basal application in garlic planting.

ii. The study showed that spacing of 20 x 20cm and NPK level of 150kg/ha gave the highest total bulbs yield/ha when compared to spacing of 30 x 20 cm and 40 x 20 cm respectively. Therefore this spacing and fertilizer level could be practiced.

iii. Optimum plant population and appropriate fertilizer regime would need to be established in in order to apply appropriate nutrients for optimal exploitation of the garlic variety used.

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