EFFECT OF BLENDED FERTILIZER (NPSB) AND FARMYARD MANURE RATES ON YIELD AND YIELD COMPONENTS OF ANCHOTE [*Coccinia abyssinica* (Lam.) (Cogn.)] AT JIMMA, SOUTH WESTERN ETHIOPIA

M.Sc. THESIS

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A Thesis

Submitted to the School of Graduate Studies, Jimma University College of Agriculture and Veterinary Medicine, in Partial Fulfillment of the Requirements for the Degree of Master of Science in Horticulture

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DEDICATION

This Thesis is dedicated to my parents.

STATEMENT OF THE AUTHOR

First, I declare that this thesis is a result of my genuine work and that I have duly acknowledged all sources of materials used for writing it. This thesis has been submitted in partial fulfillment of the requirements of Master of Science degree at Jimma University, College of Agriculture and Veterinary Medicine and is deposited at the University Library to be made available to users under rules of the Library. I solemnly declare that this thesis is not submitted to any other institution anywhere for the award of any academic degree, diploma or certificate.

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BIOGRAPHICAL SKETCH

The author, Biratu Abeshu Erandufa, was born in 1991 in Gonde Mikael Kebele, Nejo woreda, West Wollega Zone of Oromia Regional State, Ethiopia. He attended elementary school at Amuma Gute Elementery school, secondary and preparatory education at Najo Senior Secondary school. In 2011, he joined Semera University and graduated with Bachelor of Science Degree in Horticultural Science in July 2014. After graduation, he was employed at Gobu Seyo Agricultual office in Deccember 2015,and served as expert on coffee quality control and protection sector for one year. In 2016 he was employed by Wollega University as Graduate assistant . After two years of service as graduate assistant he joined the School of Graduate Studies of Jimma University in 2018 to pursue his Master of Science degree in Horticulture.

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LIST OF ACRONYMS ANDABBREVIATION

ANOVA	Analysis of variance
CEC	Cation Exchange Capacity
CV	Coefficient of variation
DM (%)	Dry matter percentage
DZARC	Debrezeit Agriculture Research Center
EHNRI	Ethiopia Human Nutrition Research Institute.
EIAR	Ethiopia Institute of Agriculture Research
FYM	Farm Yard Manure
LA	Leaf Area
LSD	Least Significant Difference
MRR	Marginal Rate of Return
MRY	Marketable Root Yield
NPSB	Nitrogen, Phosphorus, Sulfur and Boron
OM	Organic Matter
RCBD	Randomized Complete Block Design
RDF	Recommended Doze of Fertilizer
SAS	Statistical Analysis system
TRY	Total root yield

TABLE OF CONTENTS

PAGE

TABLE OF CONTENTS (*Continued*)

TABLE OF CONTENTS (*Continued*)

LIST OF TABLES

LIST OF TABLES IN APPENDICE

EFFECT OF BLENDED FERTILIZER (NPSB) AND FARMYARD MANURE RATES ON YIELD AND YIELD COMPONENTS OF ANCHOTE (*Coccinia abyssinica* (Lam.) (Cogn.)) AT JIMMA, SOUTH WESTERN ETHIOPIA

ABSTRACT

Anchote (Coccinia abyssinica (Lam.) Cogn) is an important root crop endemic to Ethiopia. It is a valuable food source and important economically, medicinally and socially. However, productivity of the crop is limited by many constraints including absence of recommended rate of fertilizer. Hence, a field experiment was conducted during 2018/19 cropping season to investigate the response of anchote variety (Desta 01) to different rates of NPSB and farm yard manure in terms of growth, yield and yield components at Jimma south western Ethiopia. The treatments consisted of six rates of blended (NPSB) (0, 58,116,175,233 and 291 kg ha^{-1}) and three levels of farm yard manure (FYM) (0, 5 and 10 t ha^{-1}). The experiment was laid out as a 3x6 factorial, arranged in randomized complete block design with three replications. The data were analyzed using SAS (version 9.3) software. The results revealed that interaction effect of blended (NPSB) and FYM fertilizer significantly ($P<0.05$) influenced days to physiological maturity, vine number, vine length, leaf number, vine internodes length, leaf area, total biomass, total storage root yield, marketable root yield, storage root diameter, harvest index, dry matter and moisture contents. Emergence percentage and vine number were significantly ($P<0.05$) affected by NPSB fertilizer, while leaf area was significantly ($P<0.05$) affected by farm yard manure. The main effect of FYM and NPSB highly significantly ($P<0.01$) affected, days to physiological maturity, vine number, vine length, leaf number, vine internodes length, leaf area, total biomass, total storage root yield, marketable root yield, storage root weight, storage root diameter, harvest index, TDM, ash, TSS, moisture and crude fat. Ash, storage root weight and crude fat were highly significantly ($P<0.01$) affected by interaction of NPSB and FRM fertilizer. However, number of storage root was not significantly affected by main and interaction effects of NPSB blended fertilizer and FYM. The highest total root yield (29.78t ha^{-1}) was obtained by applying 175 kg ha^{-1} NPSB bended fertilizers and 10 t ha^{-1}FYM. Correlation analysis showed that most yield parameters were highly significantly and positively correlated with growth and quality attributes of anchote. In terms of partial budget analysis, combined application of 175 kg ha^{-1} bended (NPSB) with 10 t ha^{-1} FYM fertilizers provided the highest return of Birr 23532.2 ETB ha^{-1} with an acceptable and highest marginal rate of return 337.32%*%. In conclusion, the results indicated that the yield and yield components and quality of Anchote at study area can be improved by the combined application of blended NPSB fertilizer and FYM. However, further study needs to be conducted in different seasons and locations by considering rates of blended and FYM fertilizers to generate more reliable information.*

Keywords: Anchote, Blended fertilizer, Farmyard manure, Storage root diameter, Root crop

1. INTRODUCTION

Anchote [*Coccinia abyssinica* (Lam.) (Cogn.)] is one of the most important endemic crops principally grown for its edible toot throughout the south and southwestern parts of Ethiopia (Ayalew, 2016). It is widely known among other root and tuber crops at around Wollega area. Anchote holds a good regard in the area due to its close traditional ties with the Oromo people. The genus in Ethiopia is not well studied, there are more than eight taxa recorded, distributed throughout the country (Lederer and Leipzig, 1996). There are about 10 species of *Coccinia* in Ethiopia. However, only *Coccinia abyssinica* is cultivated for human consumption (Bekele, 2007). Anchote is found both cultivated and wild (Edwards, 1991). Root yield of Anchote varies depending on accession. According to Mengesha *et al.* (2012), the root yield of different anchote accession ranges from 42-76 t ha^{-1}.

Anchote is a valuable food source and according to local farmers, it helps in fast mending of broken bones and displaced joints, as it contains high calcium and proteins than other common and wide spread root and tuber crops (Bekele, 2007). Traditionally, it is also believed that, Anchote makes lactating mothers healthier and stronger (Hora, 1995). Like many other root crops, Anchote is rarely eaten raw (Fufa and Urga, 1997). Anchote is important to the medicinal, cultural, social and economic life of the households. It is particularly important in cultural diets mainly between September and November in Wollega, as it is mainly harvested in these months. It is highly valued for its contributions to food security in these periods since other food crops will not be ready for consumption (Duresso, 2018). Anchote has been in use among Oromo people to prepare a variety of food items for traditional ceremonies, special food for guests and animal fattening (Bekele, 2007).

Fertilizers are one of the most important inputs of increasing the productivity of crops and modern varieties of different crops (Ali *et al*., 2009). Besides that, mineral NP fertilizers can be used to replenish soil nutrients and increase crop yields, concerns about soil exhaustion and nutritional imbalances, arising from increased and indiscriminate use of such fertilizers necessitate research on organic manure rate to assess its effect and feasibility (Bayu *et al*., 2006). Organic manures are all forms of organic soil amendments that originate from both livestock waste and crop residues with the nutrients in them being mineralized by soil microbes and slowly making them available to plants over a long period of time (Lampkin and Midmore, 2000). Farmyard manure is another source of nitrogen and other nutrients which has been used for increasing soil fertility (Darzi, 2012). Abera and Gudeta (2007) pointed out that anchote was more responsive to organic fertilizer sources. The application of organic manures has various advantages like increasing soil physical properties, water holding capacity and organic carbon content apart from supplying good quality of nutrients. Plants require organic compounds as a source of food and optimal growth (Bot and Benites, 2005).

Infertility of the soil is one of the main problem reduce productivity of the crop in Ethiopia. The challenges that contributed to Anchote production are that the farmers do not use organic and inorganic fertilizer to cultivate in most areas of production. Because, farmers' attention mostly is on field crops, cultivation of Anchote is almost handled by women who may not have sufficient money to purchase fertilizer. Expensiveness of fertilizer cost, Lack of farmer's awareness on use of fertilizer to cultivate tuber crops and utilization in non growing areas of the country and most farmers are subsistence and cannot afford o buy commercial fertilizers even for the other major crops (Duresso, 2018). In addition, there is a knowledge gap on anchote in different parts of the country on its various importances', like nutritional, cultural and medicinal and agronomic practices on how to enhance production status of anchote. The potential areas in Anchote production are mainly South and Southwestern part of the country. However, its utilization is not similar at these production areas. In Western region of the country, different items of food prepared from Anchote and different cultural foods can be prepared from Anchote. Even it is used in hotels as special food and served to people. Therefore, it needs to extend this knowledge to other parts of the country as well. Farmers cultivate local varieties of Anchote under poor management practices, such as, planting method, blanket fertilizer levels etc. Constraints such as, absence of well known cultivars morphologically and nutritionally, lack of recommendations on suitable planting time for each agro ecologies, lack of improved varieties having wider adaptation and with high yielding potential are some of the constraints contributing for under development of Anchote. Mostly Anchote is commonly produced on burned woods or ash and on plant residue. Instead of finding those plant residue while there is a trend of fertilizer application to Anchote farm our product might be improved throughout the country. According to Girma and Hailu (2007) Anchote is a short cycle crop which bulks high yield in a relatively shorter period of time and requires high fertilizer supply. There is no adequate information on fertilizer requirement of the crop.

In spite of the nutritional, social, cultural and medicinal importance of Anchote less attention has been given to enhance productivity and utilization of the crop. Due to that research out put on Anchote is very limited as a result of which shortage of published data is a common problem (Mengesha *et al.*, 2012). The combined effect of organic and inorganic fertilizer is not widely known in production of this crop. At Bako, Abera and Gudeta (2007) reported that 5-8 t ha^{-1} FYM or 46/20 kg ha^{-1}N/P are recommended for high yield of anchote production and enhancement of soil structure and its nutrient contents. Few researches have been done so far on integrated use of organic and inorganic fertilizers application pertaining to root yield and yield related components of Anchote. In Ethiopia inorganic fertilizers, particularly DAP and Urea, have been used for the last 30 years. In Ethiopia about 30% of the smallholder farmers apply some amount of the inorganic fertilizers on their farmlands (Jayne *et al*., 2003). In Ethiopia majority of the fertilizer is being used for production of cereals, mainly applied to tef, maize, wheat, barley and sorghum in that order (Rashid *et al.*, 2013). An integrated use of inorganic and organic fertilizer thought to be more preferable regarding yield and yield attributes and economic benefits of anchote. Thus, the study was carried out with the following objectives:

- **General Objective**
  - To investigate the response of anchote to different rates of NPSB and farm yard manure in terms of growth, yield and yield components.
- **Specific Objectives**
  - To determine the optimum rate of NPSB fertilizer and farmyard manure for growth, yield and quality of anchote.
  - To assess the effect of combined application of NPSB fertilizer and farmyard manure on yield and yield components of anchote.

2. LITERATURE REVIEW

2.1 Taxonomy and Morphology of Anchote

Anchote produces one root per plant and its stem is a vine like cucurbit with tendrils and usually requires staking for seed production. The vine of anchote can grow on average up to 2 m heights. Anchote produces many branched stems just at the base of the plant. It also produces large above ground biomass, which may grow at the expense of root growth and deserves some agronomic management studies. Anchote is a good source of protein, carbohydrate, calcium and iron (Getahun, 1973).

In the major group of Angiosperms (flowering plants), genus *Coccinia* is among the 115 genera belonging to the Cucurbitaceous family, one of the most economically important families of plants (Holstein and Renner, 2011; Schaefer *et al.*, 2009). The species of Coccinia are about 27 in number, and most species are widespread mainly in Sub-Saharan Africa, with centers of diversity in East Africa and Southern Africa, with the exception of C. grandis, which is spread across in the highlands of the Arabian Peninsula, tropical Asia, Pacific Islands, and the Neotropics (Holstein and Renner, 2011). From the 27 species, C. *abyssinica* (Lam.) *Cogn*.; C. megarrhiza C. Jeffrey; C. tracephylla Gilg; C. ogadensis Thulin; and C. schliebenii Harms are reported to be geographically originated in Ethiopia, while all species in this genus are categorized under dioecious plants (Holstein and Renner, 2011). *Coccinia abyssinica* is the only species cultivated for its edible rootous roots and young shoots which are used as leafy vegetables (Fikadu, 2011a; Fikadu, 2011b).

Anchote is the members of the Cucurbitaceous family, herbaceous annuals or perennials with a storage root and mostly moist vines. They grow either prostrate along the ground or climb using tendrils. Their tendrils can grow branched or simple and generated at the petiole base. There are usually four arched filaments coiling with an adhesive texture. Leaves can range from simple to palmate compound (Austin and Brendan, 2008). It has shoots with simple tendrils and leaves of which are palmately simple with five lobes, while the shape varies from the heart to pentagon form. Its flowers are unisexual having pistil-late flowers at the nodes and staminate flowers in racemes. Fruits are red yellow at maturity, and have an oval to cylindrical shape with 8.83 cm length containing an average of 153 seeds. The stems are typically sympodial in growth (Getahun, 1973).

Usually anchote root grows downwards in to the soil and never requires ridging or mound making as compared to most other root and root crops (Abera and Gudeta, 2007). Anchote can withstand dry conditions and produce food for the poor smallholder farmers when other crops fail to grow (Hailu, 2016). Anchote produces one or two roots per plant on average, and stems are vines which can grow up to 2 m in height (Abera and Gudeta, 2007). The crop is harvested 4-5 months after planting. The harvesting time stretches from September to November. Bulk harvesting can be done but the crop is more often harvested as needed. The process involves completely digging out the roots. The roots are different in shape and size

Anchote has spherical to cone-shaped roots which may vary with age, soil physical conditions and Anchote type (Duresso, 2018).Sometimes irregular shaped roots may result because of poor land preparation and the presence of mechanical barriers, which will result in the development of uncommon shaped root. The top portion of the root has the largest diameter with a rounded square in transverse section (Hora, 1995). In general, the plant has a runner growth habit with a trailing vine, which needs support for successful fruit development that provide sound seeds for future planting.

2.2 Origin and Distribution of Anchote

Ethiopia is the country in the world where crop domestication started, and considered as a primary gene centre for several crop plants (Vavilov, 1951). Similarly, it is the center of origin and diversity for anchote (*Coccinia abysinica) (*Lam.) (Cogn.) where it has been cultivated by farmers for centuries specifically in south and southwestern parts of Ethiopia (1995; Getahun, 1973).One of the common root crops cultivated in the southwestern Ethiopia highlands is anchote (*Coccinia abyssinica*) that belongs to the Cucurbitaceous family (Wayessa, 2016). It is reported that the genus Coccinia comprises 27 species. All of these species are limited to sub-Saharan Africa (Holstein and Renner, 2011).

Understanding a crop plant's geographic distribution and/or center of origin is very important for breeding, genetic improvement and conservation management activities of the crop. This is because of the nearby availability of the wild type and related species, which can provide adaptive value as well as broaden the genetic base of a crop species via out crossing. In fact, the center of origin is, usually considered as center of diversity (Sebastian, 2011). Therefore, determination of center of origin of a crop plant is important to conserve its genetic diversity, especially for those species, which are vulnerable to ecosystem fragmentation (degradation) and other anthropogenic pressures.

2.3 Importance and Status of Anchote Production

Anchote is endemic root crop of Ethiopia and it is a unique root crop in its uses and edible parts. All parts of Anchote: root, leaves and the immature fruit are consumed even though the root is the most economic concern in most growing areas of Ethiopia (Fekadu, 2011). Root and root crops have good nutritive value and photochemical contents which are beneficial to the human health. Seedling of anchote root and leaves for current use and anchote seeds for propagation generate income for growers (Duresso, 2018). It is particularly important in cultural diets mainly between September and November. It is highly valued for its contributions to food security in these periods since other food crops will not be ready for consumption. The primary product of *Coccinia abyssinica* is obviously the roots and four different type of food is can be prepared from the roots (Duresso, 2018).Anchote uses as leafy vegetable. According to Duresso (2018), tender leaves and top growing buds are plucked together like leaves tea, and cooked to be served with other especial food.

Western and southwestern provinces which are well known for production are Wollega, Kaffa, Sidamo and Ilubabaor, where other rootous of species of colocosia, dioscorea, and musa also cultivated (Yasin *et al.*, 2013).The Oromia regional state specially western part of the region is well known for the anchote production in the country. However, the cultivation is also scattered in southeastern, central and eastern Ethiopia (Bekele *et al.*, 2013).Both cultivation practice and animal pests affect anchote production. That is why, farmers often use their home gardens for anchote cultivation not only for its soil fertility, but also to protect the crop from wild animal pests such as porcupines, wild pigs, warthog and others (Hora *et al.*, 1995; Gelmesa, 2010).

2.4 The Major Anchote Production Constraints

Agro-ecological conditions and other factors (like pests) can affect anchote production and Productivity (Tolera, 2017). The pests affecting anchote production are: Porcupine, warthog, and wild pig are among a few wild animal pests of the crop. The former two pests eat anchote root by digging into the soil whereas the others consume the foliage and damage the crop by trampling on it. For commercial and higher quality anchote production, the planted area should be fenced or properly protected from damage by animal pests (Tolera, 2017).Not only its root part the fruit also infected by a kind of pests. According to Duresso (2018), fruit fly bores into the fruit and pre-disposes it to decay. The cost of commercial fertilizer suggested as the bottle neck in Anchote production. Farmers use commercial fertilizers for production of major crops because of the ever increasing prices of commercial fertilizer and they do not apply for anchote production (Duresso, 2018).

Anchote cultivation requires stacking materials that support to grow .If it creeps on the land it will be difficult to carry out cultural practices, as well as it can be a reason for infection fruits and the yield may reduced. Anchote is endemic to Ethiopia and it is not widely known to most parts of the country. Therefore, there is no adequate research done on anchote and no information about this crop. According to Mengesha *et al*. (2012), low attention has been given to the research and development of anchote, and then, there is no variety so far developed and released. The importance and utilization of anchote is rarely known in the society which mainly concentrated in Oromo Wollega. According to Fekadu *et al*. (2013), no published information is available as to which traditional processing methods are optimal to reduce the effects of the inherent anti nutritional factors and to increase availability of the contained nutrients. Anchote root shape is highly affected by the age, soil physical conditions, anchote type (genetic) and cultivation managements. The common shapes of anchote roots are spherical and conical, whereas other shapes are due to soil structure that affects its normal growth and acts as prop its tip or sides (Tolera, 2017).

Soil of Ethiopia is infertile which needs much input to enhance productivity. According to Asseffa *et al*. (2016), low soil fertility is one of the most important constraints limiting potato production in Ethiopia. Ababulgu(2018) also reported that potato production is constrained mainly by low soil fertility .Fertility of most Ethiopian soils has already declined due to continuous cropping, abandoning of fallowing, reduced use of manure and crop rotation. Boru *et al*. (2017) reported low soil fertility resulted in low sweet potato yield since the farmers do not use the inorganic and organic fertilizer. Furthermore, no awareness on cultivation practices and importance of Anchote and its usage those enable to improve cultivation, harvesting and storage that will reduce famine.

2.5 Yield of Anchote

Anchote is the most known root crop which has traditional ties with Oromo people. As its name indicates in most cases root part is the edible and the most economical important portion of anchote crop. Similar to other root and roots crops, growth of anchote root can be affected by different factors like, growing season, availability of rain fall, harvesting date, altitude and etc. According to Mengesha *et al*. (2011), yield of root and root crops is greatly influenced by conditions of growth, altitude and variety. Similarly, yield of anchote varies widely with varieties, altitude and location due to environmental differences. Time of harvesting has great influence on root size of anchote. Abera and Haile (2015), reported that anchote affected by harvesting dates and in-situ storage (at 4, 7, 10, 13 and16th months).

When anchote root stayed in the soil above one season it called Guboo in Afan Oromo.The Guboo anchote is suggested as it has medicinal value. The reason why it has large size and medicinal value guboo anchote can be sold by large price. The price for anchote roots varies with root size, time of the year, supplies amount and market location (Duresso, 2018).

2.5.1 Root dry matter

The root dry matter content was affected by a wide range of factors that affected the growth and development of the crop including most importantly, environmental factors such as intercepted solar radiation, soil temperature, available soil moisture and cultural treatments. Dry matter contents are associated with the amounts of starch, proteins and mineral constituents present (Nazi *et al*., 2011).

The dry matter content of root is an important measure of quality and is used to assess Suitability for processing purposes as it affected process efficiency, product yield and oil absorption (Ababulgu, 2018). It was observed that roots with high dry matter content required less energy input during frying or dehydration to remove water; resulted in greater product yield per unit fresh weight than roots with lower solids content and absorbed less oil during frying (Ababulgu, 2018

2.6 Nutrient Composition of Anchote

Nutritional value is the main concern when a crop is considered as a food source. Anchote is endemic root crop used as a food source in parts of Western Ethiopia. Anchote contains appreciable quantity of carbohydrate, crude Protein, crude fiber, calcium, magnesium, iron and low levels of ant nutrients (Oxalate, tannin and cynide) except phytate when compared to other reported raw roots and roots (Fikadu *et al*., 2013). The relationship of different nutrients with protein, organic matter and ash appears to be different for leaf and root plant parts of Anchote (Abera and Haile, 2015).

2.6.1 Moisture

Moisture content is defined as the mass of water per unit mass of dry mater. Understanding the water content of material is a common interest and concern to many diverse industries. Moisture content is important for the processing and handling of cosmetics, pharmaceuticals, food, personal care products, pulp and paper products and specialty chemicals to name just a few (Guma, 2014).

Moisture content determination is an integral part of the proximate composition analysis of food (Fikadu *et al*., 2013). The moisture content of Anchote boiled after peeling is significantly higher than both boiled before peeling and raw anchote roots. Similarly, the mean moisture content of anchote boiled before peeling is significantly higher compared to mean raw anchote. The moisture content is increased in boiling after peeling by 9.08% and in boiling before peeling 2.41% compared to raw roots. The increased moisture content might be due to the water absorption capacity of fibers and other natural chemical components during heat treatment (Fikadu *et al.,* 2013).

2.6.2 Crude fat

Fats are very important for the body and are the biggest source of energy providing 9.1 k.cal $100g^{-1}$. Fats are important for the proper functioning of nervous system and maintain fertility in man. Fats act as lubricant in the alimentary canal of man (Nazi *et al.,* 2011). Fat in food determines the amount of energy available (Ayalew, 2016). A diet providing 1-2% of its caloric energy as fat is said to be sufficient for human beings as excess fat consumption yields certain cardiovascular disorder such as atherosclerosis, cancer and aging (Sodamade *et al*., 2013).

2.6.3 Total ash

The mean total ash content boiled after peeling is lower than both boiled before peeling and raw Anchote roots (Fikadu *et al,* 2013). According to Fikadu (2017), total ash content is directly proportional with inorganic element content of Anchote. Hence, the samples with high percentages ash contents are expected to have high concentrations of various mineral elements, which are advantageous to speed up metabolic processes and improve growth and development. The slight differences in the total ash content might be related to the soil types, stage of maturity and agronomic practices. In reference with the raw roots, the total ash content of Anchote boiled after and before peeling decreased. The reduction of total ash may be due to leaching of the mineral compound and water absorption during boiling (Fikadu *et al,* 2013). Ash content is the best reflection of the mineral content of the food material (Gemechu, 2018).

2.7 Importance of Organic Fertilizers for Crop Production and Soil Fertility

Application of organic fertilizers such as Farmyard manure and compost play an important role in the improvement of soil structure and cation Exchange Capacity (CEC), especially in many highly weathered tropical soils where the inherent CEC is often low (Onwudike, 2010) Organic material is used to prevent or improve the negative stresses effects in plants and yield decreasing. It is material to decrease soil salinity. Increase the organic matter, improve the soil structure and increase water and air permeability by root developing in soil. It is one the best used fertilizers (Hassanpanah and Azimi, 2012).

Soil fertility aspects enhanced by the maintenance of the organic matter include the direct contribution of nutrients, influence on cation exchange capacity and binding of heavy metals and pesticides. In plant nutrition, organic matter level of the soil is the key property that determined the availability status of essential nutrients (Katyal, 2000). Conservation and sustenance of organic matter, therefore, is remained the mainstay of soil quality (Katyal, 2000).

Anchote responds strongly to soil fertility, particularly to wood ash and produces large sized root of good shape very rapidly when grown in fertile soils. Growers know this from their long practical experience and hence prefer to grow anchote close to the home garden where a cattle pen can be put up and rotated. This makes cow dung available as organic manure. Other areas within the reach of the family can also be made suitable for anchote through the use of other waste as organic manure in addition to that from cow dung (Getahun, 1973).

2.7.1 Farmyard manure

Farmyard manure benefits both the soil and the crop. It improves the tilth of heavy soils, and increases the water holding capacity of light soils. The full benefit of farmyard manure is obtained only when the soil is well cultivated, well drained, and well limed (Dandotiya *et al*, 2015). Animal waste can make substantial contribution to nitrogen, phosphorus, potassium and other nutrient needs. Total supply however, depends on the nature and size of animal enterprises and methods used in decomposing, storing and application of the manure (Kassa, 2003; Dandotiya *et al*., 2015). Nitrogen from manure is lost from the soil. In fact some loss is inevitable no matter how the manure is stored or applied. Phosphorus and potassium losses are less likely except through direct run off and leaching from open storage lots or as a result of setting in open lagoons.

Farmyard manure can improve chemical, physical and biological characteristics of soil (Banuelon, 2008) probably increases available P, mineralized N and improved cations exchange capacity of the soil, increases of hydraulic conductivity, raising the water holding capacity, changing the soil pH (decrease or increase in the pH, depending on soil type, elevating the soil aggregation and water infiltration, reducing the frequency of plant diseases (Olson and Papworth, 2006)

At Bako Agricultural Research Center, the results of research done on anchote in 2002 and 2004 E.C showed that anchote which farm yard manure is applied on the experiment, produce vigorous, deep green and strong vine. And, the supply of FYM significantly influenced root yield(Abera and Gudeta,2007).In a nutshell, the positive response of anchote to both organic and inorganic fertilizer supply is corroborated by laboratory soil test that indicated the very low nutrient content of the study soil with regard to total N, available and total P and OM. According to Girma and Hailu (2009), 5-8 t ha^{-1} farm yard manure (FYM) or 46/20 kg ha^{-1} N/P are recommended for high yield of anchote production and enhancement of soil structure and its nutrient for the western sub-humid zones of Oromia, Ethiopia.

2.7.2 Combined application of organic and inorganic fertilizers

Integrated nutrient management implies the maintenance or adjustment of soil fertility and of plant nutrient supply to an optimum level for sustaining the desired crop productivity on one hand (Masrie *et al.,* 2015) and to minimize nutrient losses to the environment on the other hand (Singh *et al.,* 2002). It is achieved through efficient management of all nutrient sources (Singh *et al*., 2008). According to these authors, sources of nutrients in the soil for a plant include soil minerals and decomposing soil organic matter, mineral and synthetic fertilizers, animal Manures and composts, by products and wastes, plant residue, and biological N-fixation

The integrated use of both manure and chemical (inorganic) fertilizers is the best alternative to provide balanced and efficient use of plant nutrients and increase productivity of soil (Goletti, *et al.*, 2000). Anchote is responsive to different organic sources and influences of nutrient supply on basic biochemical composition of anchote. In a nutshell, the positive response of anchote to both organic and inorganic fertilizer supply is corroborated by laboratory soil test that indicated the very low nutrient content of the study soil with regard to total N, available and total P and OM (Girma and Hailu,2007). The combined application of mineral NP and cattle manure (CM) gave a better result than the application of sole, which indicates integrated nutrient management is the best method for soil fertility management **(**Zewide *et al*.,2018).

2.8 Response of Anchote to Organic and inorganic Fertilizers

Anchote responds strongly to soil fertility, particularly to wood ash and produces large sized root of good shape very rapidly when grown in fertile soils. The positive response of anchote to P supply was probably related to its deep root growth that facilitates more soil P reserve exploitation as compared to potato and sweet potato (Abera and Gudeta, 2007). According to Duresso (2018), *Coccinia abyssinica* is highly responsive to commercial fertilizer. According to Owolabi *et al*. (2016), inorganic fertilizer application had significant effects on J. *curcas,* as the lowest values of the measured parameters were obtained with no fertilizer application throughout the periods of evaluation with optimum fertilizer rates resulting in significantly higher values of the measured parameters.

Anchote is more productive on fertile soils that have wood ash and charcoal substances. This indicates that anchote needs carbon contain soil and other minerals. According to Kofman (2016), wood ash contains most of the minerals that a tree will take up during its lifetime. These comprise three main categories: macronutrients micronutrients heavy metals. Macro nutrients include elements such as phosphorus, potassium, calcium and magnesium. Micronutrients include iron, sodium, manganese and copper. Sulphur and nitrogen are also nutrients, but these are mostly vented in the flue gasses. Heavy metals are also absorbed in tiny amounts during growth and end up in the ash. These include zinc, lead, cobalt and cadmium amongst others (Kofman, 2016). The generated wood ashes are alkaline in nature and contain essential nutrients needed for development of different plant species (Serafimova *et al*., 2011).

3. MATERIALS AND METHODS

3.1 Description of the Study Area

The experiment was conducted in Ethiopia, Oromia in Jimma on JUCAVM experimental site called Horticultural garden in the year of 2018/19 under irrigation condition from September to January. The study area is located at approximate geographic coordinates of latitude 06°36' N and longitude of 37°12' E at an altitude of 1710 m above sea level. It receives an annual average rainfall of 1500 mm and has mean minimum and maximum temperatures of 11.4°C, and 26.8°C, respectively. The mean minimum and maximum relative humidity are 39.92% and 91.4% respectively (Melaku, 2008).

3.2 Description of the Experimental Materials

The plant material, Anchote variety used for this study was Desta 01. It was released by Debre Zeit Agricultural Research Center, Ethiopia Institute of Agriculture Research (DZARC/EIAR) in 2018. The variety has a potential of 32.5t ha^{-1} with creamy root flesh color and with wider adaptability, high land to mid lowlands (DZARC research manual, 2018).

3.3 Treatments and Experimental Design

The treatments consisted of six levels of NPSB fertilizer (0, 58, 116, 175, 233 and 291 kg ha^{-1}) and three levels of farmyard manure (FYM) at rates fertilizer (0, 5 and 10 t ha^{-1}). Locally available and decomposed farmyard manure (FYM) was used as a source of organic fertilizer. The trial was laid out as 6x3 factorial arranged in Randomized Complete Block Design (RCBD) with three replications. Each treatment combination was assigned randomly to the experimental units within a block. There were 54 plots corresponding to the 18 treatment combinations with unit plot size of 2 m x 2 m (4 m^2)(Table 1) and with spacing of 40 cm between rows and 10 cm between plants.

Table 1. Description of treatment combination.

Treatments	NPSB Rate (kg ha^{-1})	FYM Rate (ton ha^{-1})
T1	0	0
T2	0	5
T3	0	10
T4	58	0
T5	58	5
T6	58	10
T7	116	0
T8	116	5
T9	116	10
T10	175	0
T11	175	5
T12	175	10
T13	233	0
T14	233	5
T15	233	10
T16	291	0
T17	291	5
T18	291	10

3.4 Experimental Procedures

The experimental field was cleared and ploughed using oxen and plots were leveled manually. Seeds were planted on well prepared five rows per beds at 5 cm depth in the soil. Sowing was done in September 30, 2018. In the designed plots two seed per hill were planted. The source of FYM was well dried cow dung that was collected from animal farm of JUCAVM, which had been stored and piled for proper decomposition before application. The manure was utilized when it turns its colour to brown, well decomposed, and minimal foul odour and was applied before one month of sowing the seed by broadcasting method on allotted treatment or plot. This was done to ensure complete decomposition of organic manure.

Blended NPSB fertilizer was applied on sowing time by specified rate and depth of placement in the soil. Seeds were planted directly on the beds. All relevant cultural practices such as watering, weeding, hoeing and stacking activities were undertaken accordingly. Stacking was done when the crop produced a vine to enable anchote vine to grow up. Stacking can be made up of living plants, live fence, dead wooden poles, or wire poles erected for the purpose. The crop was grown under irrigation managements, so water was applied as per requirement of the crop. Harvesting was done in February 2019 when more than 90% of the plants in a plot show physiological maturity (at >90%) leaves shown senescence.

3.5 Pre-planting Soil Chemical Properties and Farmyard Manure Result

One representative composite sample was taken at a depth of 0-30 cm diagonally across the experimental field using auger before planting and bulked. The sample was air dried and grinded using a pestle and mortar and sieved with a 2 mm mesh. Farmyard manure was also analyzed for chemical composition. Working samples were analyzed and determined for selected physico-chemical properties mainly texture, soil pH, cation exchange capacity (CEC), total N, available P and organic matter and texture using standard laboratory procedures. Organic matter content of the soil was determined by the volumetric method (Hazelton and Murphy, 2007).

Total N was analyzed using indigestion, distillation and titration method as described by Ethio SIS (2014), by oxidizing the organic matter in concentrated sulfuric acid solution (0.1N H_2SO_4). The pH of the soil was determined on 1:2:5 (weight/volume) soil samples to water ratio using a pH meter (Motsara and Roy, 2008). Cation exchange capacity (CEC) was measured titrimetrically by distillation of ammonium that was displaced by sodium from NaCl solution (Landon, 1991). On the other hand, available phosphorus in Farm yard manure was determined by using procedures of Ethio SIS for estimation of available Phosphorus in Soils by Extracting with Sodium Bicarbonate (Ethio SIS, 2014).

Table 2.Physicochemical properties of the experimental site soil and farm yard manure (FYM) before planting.

Parameters	Values		Rating.	Reference
	Soil	FYM		
pH	5.5	7.43	Moderately Acidic and Moderately alkaline	Landon (1991)
OC%	3.65	31.68	Medium and very high	Hazelton and Murphy (2007)
OM%	6.29	54.63	Medium and very high	Hazelton and Murphy (2007)
TN	0.31	2.73	Very High and very high	EthioSIS (2014)
CEC	29.59	115.42	High and very high	Landon (1991)
AV.P(ppm)	16.60	2223.8	High and very high	Ethio SIS (2014)
Physical Properties			Textural Class	
Sand	20%		Clay loam	Anderson and Ingram**,**1993
Clay	46%			
Silt	34%			

Where pH = hydrogen power, % OM =percent of organic matter, CEC = Cation exchange capacity, %TN = Percent of total nitrogen.ppm = AVvp.ppm=available phosphorus in parts per million.

3.6 Data Collected

Growth data were collected during the field experiment by sampling 15 randomly taken and pre-tagged plants from the central rows of net plot. Days to maturity were registered on plot basis. Yield data were collected from the net plot, while yield components were collected either from 15 randomly taken plants or net plot and the average was worked out.

3.6.1 Phenological observation

Emergence percentage (EP) was calculated after 20 days of sowing by counting number of seeds that emerge from each plot and dividing by the total planted and then plot's average was taken.

Days to physiological maturity was recorded when 90% of the leaves of the plants in each plot become yellow, dry and/or show senescence.

3.6.2 Growth parameters

Vine number (VN): Number of vines per single hill was counted after the maturity of the plant (i.e., four months after sowing), from sampled plants of each of the 15 randomly taken plants on each plot and then average was worked out.

Vine length (VL): Vine length was measured after the maturity of the plant (at four months of sowing in meters from base to tip of the plant from 15 random plants of each plot and then average was worked out.

Vine internode length (VIL): It was measured after the maturity of the plant (four months after sowing) and was expressed in centimeter by taking the representative part or the middle portion of vines from 15 sampled plants.

Number of leaves (NoL): It was recorded from 15 randomly taken plants at two, three and four months after sowing, and the sum total was considered for analysis.

Leaf area (LA): Leaf area was measured on graph paper that has one centimeter square grid lines and the numbers of grid squares that are inside of the leaf on the paper were the area of the leaf. Leaf area was measured from the middle parts of the plant by selecting 15 leaves at random from each plot at full maturity stage.

Total biomass yield (TBMY): It was obtained by measuring the total above and below ground biological yield in kg from each plot at harvest.

3.6.3 Yield and yield components

Number of storage roots (NR): The average number of storage roots per single hill (the clustered number of storage roots per plant) was determined by counting from 15 randomly taken plants from each plot.

Storage root diameter (SRD): The diameter of roots was measured at the middle of root from 15 randomly selected storage roots and was expressed in millimeter.

Total storage root weight (TRW): The clustered number of storage roots per plant was counted from randomly taken 15 sample plants and the same was measured using a sensitive balance (BP 1600-S) and was expressed in kilogram (kg).

Total storage root yield (TRY): The total root yield was measured in tons per hectare from the sampled plants to the overall plots.

Harvest index: It was recorded as the proportion of the total fresh weight of the root to the total fresh biological yield. This was calculated as:

$$HI = \frac{EY}{BY} X100$$

Where, EY: weight of matured fresh root (Economic Yield);

BY: weight of biological yield (above and below ground fresh weight).

3.6.4 Quality parameters

Dry matter content of roots (DMC) (%): Five roots of all size category were randomly taken from each plot, weighed, washed, peeled, sliced (cut into thin slices) and put in an oven dry at 72^{o}C until constant weight was reached and root dry matter content was estimated as the ratio of the weight of dried roots to the fresh weight of the same sample root expressed as a percentage which was later used in all quality parameters working.

$$DM(\%) = \frac{WTDM}{WTFW} X100$$

Where: DM (%) = Percent Root Dry Matter, WTDM = Weight of dried sample roots WTFW = Fresh Weight of the same sample before drying.

Crude fat: Ether extract method was used to determine the crude fat using soxhlet extraction apparatus by the official method 4.5.01(Baena *et al.*, 2003). Two grams of moisture free sample was weighed in to each of the extraction thimbles (Whatman International LTD Maidstone, England) wrapped with two centimeters layer of fat free cotton. Cleaned and dried receiving beakers were first weighed filled with 70 ml of diethyl ether (Sigma-Aldrich, USA) and fitted into the soxhlet apparatus [i](Shanghai Qianjian Instrument Co., Ltd) for the extraction process. After four hours of extraction, the ether in the receiving beakers were allowed to evaporate in a drying oven (Cintex precision, India) at 92^{o}Cfor at least 30 minutes, and then cooled inside desiccators. Finally, the percent crude fat content was determined by using the following formula:

$$\text{Crude fat}(\%) = \frac{(We - W0)}{(Ws \times \%DM) \times 100}$$

Where:

We: weight of aluminum cup

W0: Weight of dried aluminum

Ws: weight of the sample

DM: dry matter percent

Moisture: Moisture content was determined according to AOAC (2000), using the official method 925.09. Crucibles made of aluminums were washed and dried in drying oven and allowed to cool in desiccators (CSN-SIMAX). The mass of each dried crucibles was taken first (M_1), and about 5 g of sample was weighed in clean and dried crucible (M_2) using analytical balance (Adventurer, OHAUS, China).The crucibles containing the samples were then put in an oven set at 105 ^oC to dry the sample to constant weight (M3). Finally, moisture content was calculated by using the following equation;

$$\text{Moisture (\%)} = \frac{m2-m3}{m2-m1}*100$$

Where;

M3: Mass of the crucible and the sample after drying

M2: Mass of the crucible and the sample before drying

M1: Mass of the crucible

Total soluble solid: Total soluble solid was determined by using a Hand Refract meter from the extract of anchote root. Two gram of anchote powder was weighted by sensitive balance. Two ml of normal distilled water was added in to the beaker and mixed with prepared powder by stirrer. After it mixed thoroughly the soluble form of product was put on a soft cloth and squeezed to refract - meter to identify the total soluble solid.

Total ash: Total ash content was determined according to AOAC (2000), using the official method 923.03. The crucibles were first cleaned and dried in an oven at 100 oC and cooled in desiccators before the mass of each crucible was weighed by analytical balance (LA 204, Measure tech.) (M1). By taking 4 gram sample (M2) the crucibles were thoroughly charred on hot plate starting from low temperature under a hood (Nordia, London E17 6AB), and then placed in a muffle furnace (Carbolite CSF, 1200) at about 550 ^oC until the sample changed to grayish white ash which took about five hours. To take the final mass (M3) the crucibles that contained-ignited sample were cooled inside desiccators (CSN-SIMAX). Finally, the total ash content was calculated using the following equation:

$$Ash(\%) = \frac{M3-M1}{M2=M1}X100$$

Where:

M1: Mass of the dried dish.

M2: Mass of the dish and the sample

M3: Mass of the dish and the sample after ashing

3.6.5. Soil parameters

Soil particle size distribution (texture): It was determined before planting using Bouyoucos hydrometric method following the procedure described by (Anderson and Ingram, 1993)

Soil pH: Soil sample before planting (composite) and after harvest (from each treatment) was taken, analyzed and pH determined by using pH meter (Landon, 1991).

Soil organic carbon and organic matter content (%): It was determined before planting and after harvest by using procedures described by Hazelton and Murphy (2007) and organic matter (OM) was calculated using organic carbon content.

Total N content of the soil (%): It was analyzed before planting (composite) and after harvest (from each treatment) and determined using Micro Kjeldahl method by oxidizing the OM with sulfuric acid in sulfuric acid solution (Ethio SIS, 2014).

Soil available P (ppm): It was analyzed before planting and after harvest, colourimetric measurements were taken after extraction of soil samples by sodium bicarbonate ($NaHCO_3$) solution at pH8.5, following the procedure outlined by Ethio SIS, 2014).

Soil Cation Exchange Capacity (CEC): It was determined by ammonium acetate method after leaching the ammonium acetate extracted soil samples with 10% NaCl solution. Determined from ammonium acetate saturated samples through distillation and measuring the ammonium using the modified Kjeldahl procedure as described by Landon (1991).

3.7 Partial Budget Analysis

Partial budget analysis was employed for economic analysis of fertilizer application and it was carried out for root yield. The potential response of crop towards the added fertilizer and price of fertilizers during planting ultimately determine the economic feasibility of fertilizer application (CIMMYT, 1988). To estimate economic parameters, Anchote root was valued at an average open market price of 12.00 birr kg^{-1}. To estimate the total costs, mean current prices of NPSB (16 Birr kg^{-1}) and farm yard manure (250 birr t^{-1}) were considered. In addition, the cost of farm yard manure preparation, transportation and its application(150ETB/ton) + cost of NPSB blended fertilizer and its transportation and application (200 ETB/100kg)+ Anchote root yield harvesting and transportation cost (40 ETB/ton) were included in the calculation. The economic analysis was based on the formula developed by CIMMYT (1988) and given as follows:

Total root yield (ton ha^{-1}): is an average yield of each treatment.

Adjusted yield (AJY): is the average yield adjusted downward by a 10% to reflect the difference between the experimental yield and yield of farmers. AJY = TRY - (GAY * 0.1) Gross field benefit (GFB): was computed by multiplying field/farm gate price that farmers receive for the crop when they sale it by adjusted yield. GFB = AJY * field/farm gate price of a crop.

Net benefit (NB): was calculated by subtracting the total variable costs from the gross field benefit for each treatment. NB = GFB – TVC

Marginal rate of return $(MRR(\%) = \frac{NB2-NB1}{TVC2-TVC1}*100$ (CIMMYT, 1988).

Therefore the treatment which was non-dominant and having a MRR of greater or equal to 50% with the highest net benefit was taken to be economically profitable.

3.8 Data Analysis

All measured data were checked for assumption of analysis of variance and subjected to analysis of variance (ANOVA) using SAS (Statistical Analysis Software) version 9.3 (SAS Institute Inc, 2014). Mean separation was carried out using Least Significant Difference (LSD) test at 5% level of significance. Pearson's Correlation analysis was also conducted for growth, yield and yield components and quality of anchote.

The following model for factorial RCBD was used:

$y_{ijk} = \mu+\alpha_i+\beta_j+ r_k+ (\alpha\beta)_{ij}+ e_{ijk}$,

Where, y_{ijk} = the response measures for the ijk^{th} observations

μ = the overall mean effects

α_i = the effects of ith level of fertilizer

β_j = the effects of jth level of farm yard manure

r_k =the effect of kth replication

$(\alpha\beta)_{ij}$ = the effects of the interaction effects between fertilizer level and farmyard manure,

e_{ijk} = the random error compared for the whole factor

k = number of replication

4. RESULTS AND DISCUSSION

Combined effect of blended NPSB fertilizer and farmyard manure on yield and yield component variables of Anchote are presented and discussed as follows.

4.1 Phenological Observation

4.1.1 Emergence Percentage

The result of analysis of variance showed that application of NPSB fertilizer and FYM significantly ($P<0.05$) and highly significantly ($P<0.01$) affected the emergence percentage, respectively. However, the interaction between NPSB and FYM did not show significant effect ($P>0.05$) on emergence percentage of Anchote (Appendix Table 2). The highest value of emergence percentage (82.08%) was scored as the result of application of 291 kg ha^{-1} of blended NPSB fertilizer, which, however was not statistically different from the values obtained as a result of application of 233 kg ha^{-1} (81.18%), 175 kg ha^{-1} (80.091), 116 kg ha^{-1} (75.024%) and 58 kg ha^{-1} (78.36%) of blended NPSB fertilizer. While the lowest value (75.01%) was scored at the control. Increasing application of NPSB from zero to 291 kg ha^{-1} has enhanced emergence percentage by 9.43% (Table 3).

The highest emergence percentage (84.33%) was scored as a result of application of 10 tha^{-1}farmyard manure, which however, was not statistically different from the value (82.31%), obtained due to application of 5 tha^{-1}farmyard manure. The lowest emergence percentage (69.23%) was recorded at the control (Table 3). Sole application of 10 t ha^{-1} farmyard manure increased percentage of emergence by 21.81% over the control. This was more than twofold of the value scored from blended NPSB fertilizer. Therefore, this study showed that farmyard manure had more contribution than blended NPSB fertilizer in germination of Anchote seed.

The abundance and early emergence of the seedling from the amended soil might be due to loosening and softening of the soil after decomposition of farmyard manure that improve structure of the soil, and in turn enabling seedlings to emerge easily from the soil. It might also be because blended NPSB is the immediate source of energy, taken up by plant root and hasten growth potential of the emerging seed. This is in conformity with the finding of

Lemma (2018), who reported early emergence of the seedlings of Roselle from the soil might be due to improved aeration and moisture holding capacity of the soil facilitated by FYM. It also corroborates with the findings of Morgan (2007), who reported that FYM improves soil structure and aeration and increases the water-holding capacity of the soil and the faster and higher percentage of seed germination was obtained because of FYM application in okra. On the other hand, application of inorganic fertilizer at the time of planting stimulates better crop emergence especially in N deficient soil (Rurinda *et al.*, 2014)

Table 3.Effect of Blended (NPSB kg ha^{-1}) and farmyard yard manure (t ha^{-1}) fertilizer on days to emergence of Anchote at Jimma during 2019 cropping season

Treatments (NPSB Kg ha^{-1}	Emergence Percentage (%)
0	75.01^{b}
58	78.36^{ab}
116	75.024^{ab}
175	80.091^{ab}
233	81.18^{a}
291	82.08^{a}
LSD (0.05)	5.38
CV (%)	7.15
Treatments FYM tha^{-1}	Emergence Percentage (%)
0	69.23^{b}
5	82.31^{a}
10	84.33^{a}
LSD (0.05)	3.81
CV (%)	7.15

Key. Means sharing common letter(s) are not significantly different at 5% level of significance

4.1.2 Days to physiological maturity

The present study revealed that the two main effects (FYM and NPSB fertilizer) highly significantly ($P<0.01$) affected days to maturity of Anchote (Appendix Table 2). Similarly, it was significantly ($P<0.05$) affected by the interaction of the two fertilizers (Appendix Table1). The highest days to physiological maturity (149.38) was observed at combined application of 291 kg ha^{-1} NPSB with 10 t ha^{-1} farmyard manure fertilizer, which however, was not statistically different from the values (147.42) obtained due to combined application of (233 kg ha^{-1} NPSB plus 10 t ha^{-1}FYM) and (146.17) (175 kg ha^{-1} plus 10 t ha^{-1}FYM) fertilizers. While the lowest (119.33) days to physiological maturity was observed at the control, which however, was not statistically different from the values 121.38, 124.42 and 123.17 obtained as the result of combined application of 0 t ha^{-1} FYM plus 58 kg ha^{-1} blended NPSB, 0 t ha^{-1} FYM plus 116 kg ha^{-1} blended NPSB fertilizer and 0 t ha^{-1} FYM 175 kg ha^{-1} blended NPSB fertilizer, respectively (Table 4).

The combined application of 291 kg ha^{-1} blended NPSB fertilizer and 10 t ha^{-1} farm yard manure delayed days of physiological maturity by 13.67 % over 291 kg ha^{-1} blended NPSB fertilizer, 12.93% over 10 t ha^{-1} farm yard manure and 25.18% over the control. Increasing rate of blended NPSB fertilizer and farm yard manure positively influenced physiological maturity. Furthermore, individual application of 291 kg ha^{-1} blended NPSB fertilizer delayed days to physiological maturity by 11.44%, and application of 10 t ha^{-1} farm yard manure delayed days to physiological maturity by 13.39% in contrast to the control.

This difference may be due to shortage of nutrients in the untreated plot and adequate supply of nutrient in treated plots. Similarly, availability of nitrogen in NPSB fertilizer and farm yard manure could be reason for delayed maturity of anchote. That is why, the plants received high amount of inorganic and organic fertilizer remained vegetative and green for longer time as compared to control plots. This result agrees with report on potato, by Mohamed *et.al.* (2018) who reported the interaction of different rates of inorganic fertilizers with various levels of FYM has a significant effect on days to maturity. The decrease in day to maturity continued up to the highest level of the nutrient (111 kg N ha^{-1}+ 92 kg P_2O_5 ha^{-1} + 10 ton FYM ha^{-1}).

In the present study, Anchote plots which received FYM produced vigorous, deep green and strong vine. Abera and Gudeta (2007) reported similar result that the plants remained vegetative and green for longer as compared to the plants that received inorganic fertilizer. According to Haile (2004), the crop with more nitrogen will mature later in the season than a crop with less nitrogen because late growth (maturity) is related to excessive haulm development while early root growth (maturity) is related to less abundant haulm growth.

Table 4. The interaction effect of farmyard manure (t ha^{-1}) and (NPSB (kg ha^{-1}) Blended fertilizer on days of physiological maturity of anchote at Jimma during 2019 cropping season.

Treatments NPSB rates kg ha^{-1}	Days of Physiological maturity. FYM rates t ha^{-1}		
	0	5	10
0	119.33^{j}	127.12^{ghi}	132.28^{fg}
58	121.38^{j}	128.82^{gh}	137.92^{de}
116	124.42^{hij}	124.42^{hij}	136.25^{ef}
175	123.17^{ij}	138.38^{de}	146.17^{abc}
233	129.38^{gh}	142.48^{bc}	147.42^{ab}
291	131.42^{fg}	141.25^{dce}	149.38^{a}
LSD(0.05)	5.39		
CV (%)	2.46		

Key. Means sharing common letter(s) are not significantly different at 5% level of significance

4.2 Growth Parameters

4.2.1 Vine number

The present study showed that the number of vines was significantly ($P < 0.05$) influenced by the interaction of NPSB and farmyard manure (Appendix Table1). Similarly, the main effects of NPSB and farmyard manure highly significantly ($P< 0.01$) affected number of vines (Appendix Table1). The highest number of vines (5.07) was scored as the result of combined application of 291 kg ha^{-1} of NPSB plus 10 t ha^{-1} of FYM fertilizer, followed by the value (4.69) scored due to combined application of 233 kg ha^{-1} of NPSB plus 10 t ha^{-1} fertilizers. While the lowest number of vines (2.87) was obtained from the control treatment, which was statistically on par with the value (2.92) obtained as the result of combined application of 0 t ha^{-1} of FYM plus 58 kg ha^{-1} of blended NPSB fertilizer (Table 5).

The integrated application of 291 kg ha^{-1} blended NPSB fertilizer and 10 t ha^{-1} farm yard manure increased vine number by 34.48 % over 291 kg ha^{-1} blended NPSB fertilizer, 19.29 % over 10 t ha^{-1} farm yard manure and 76.67 % over the control. This might be attributed to increased supplies of numerous plant nutrients from farmyard manure and inorganic fertilizer to the plants, which might have promoted the growth of lateral shoots. And, it might be associated with stimulated plant metabolic activities, which resulted in more photosynthetic efficiency, favored initiation and extension of growth of effective vines per plant. Fliert and Braun (2000) stated that above ground growth was inversely related to storage root bulking as assimilates goes to the more bulking region. It also corroborates with the finding of Ababulgu (2018), who reported that potato grown with the highest rate of NPS blended fertilizer (150 kg ha^{-1}) recorded higher main stem number.

4.2.2Vine length

The vine length was highly significantly ($P<0.01$) affected by main effect of blended (NPSB) and FYM Fertilizer **(**Appendix Table1**)**. Likewise, the interaction effect of FYM and NPSB significantly ($P<0.05$) affected vine length (Appendix Table1). The highest vine length (3.01m) was obtained as the result of combined application of 10 t ha^{-1} FYM plus 291 kg ha^{-1} of NPSB fertilizer, which however, was not statistically different from the values (2.86 m and 2.97 m) scored due to combined application of 233 kg ha^{-1} of NPSB plus 10 t ha^{-1} of FYM fertilizer, and175 kg ha^{-1} plus 10 t ha^{-1} FYM fertilizer, respectively. While the lowest vine length (1.67m) was recorded at the control, followed by the value (1.71m) recorded due to combined application of 0 t ha^{-1} of FYM plus 58 kg ha^{-1} NPSB fertilizer (Table 5).

Combined application of 291 kg ha^{-1} blended NPSB fertilizer and 10 t ha^{-1} farm yard manure increased vine length by 44.3 % over 291 kg ha^{-1} blended NPSB fertilizer, 28.21 % over 10 t ha^{-1} farmyard manure and 79.64 % over the control. The growth of vine in Anchote is proportional to application of farm yard manure and NPSB fertilizer when implemented with all other relevant cultural practices. The increase in vine length in response to increased rate of FYM may be due to increased availability of water in the root zone of the plants under a soil moisture stress condition, which is quite common in rain-fed farming (Hati *et al.*, 2007). Boru *et al.* (2017) also reported increase in sweet potato vine growth with increasing rate of FYM. Halvin *et al.* (2005) also identified that farmyard manure in combination with inorganic fertilizers play an important role in better penetrations and establishment of crop roots, and the better roots help the plant to utilize water from deeper layers that may have enhanced vegetative growth through increasing cell division and elongation.

4.2.3 Vine internode length

The analysis of variance showed that vine internode length (VIL) was significantly ($P < 0.05$) affected by the interaction of blended (NPSB) fertilizer and farmyard manure (Appendix Table1). The main effects of blended NPSB fertilizer and farm yard manure was highly significant (P <0.01) for VIL (Appendix Table 1). The highest vine internode length (15.92cm) was scored as the result of combined application of 291 kg ha^{-1} of NPSB fertilizer plus 10 t ha^{-1} of FYM fertilizer, followed by the value (14.92cm) scored due to combined application of 233 kg ha^{-1} NPSB plus 10 t ha^{-1} of FYM fertilizer (Table 5). Whereas, the lowest value (9.89cm) was recorded at the control treatment, followed by the value obtained as the result of combined application of 0 t ha^{-1} FYM plus 58 Kg ha^{-1} of blended NPSB fertilizer (Table 5).

Combined application of 291 kg ha^{-1} blended NPSB fertilizer and 10 t ha^{-1} farmyard manure increased vine Internodes length by 30.07% over 291 kg ha^{-1} blended NPSB fertilizer, 15.69 % over 10 t ha^{-1} farm yard manure and 60.79 % over the control. Similarly, application of 291 kg ha^{-1} blended NPSB fertilizer without farm yard manure increased vine internode length by 16.35% The increase in VIL might be due to interaction of NPSB and FYM treatments might be due to the nutrients released from FYM and NPSB fertilizers, which contributed to plant growth parameters by increasing vine of the plant and number of leaves per plant. This finding is closely similar with the finding of Beji (2017) who described increase in the applied N from 0 to 90 kg ha^{-1} significantly increased internode length by 0.20 cm.

4.2.4 Number of leaves

The analysis of variance showed that the main effect of Blended(NPSB) and farmyard manure fertilizer on number of leaves was found to be highly significant(P < 0.01), whereas the interaction effect of Blended (NPSB) and farmyard manure was significant (P <0.05) (Appendix Table 1). The highest leaf number (64.92) was scored as the result of combined application of 291 kg ha^{-1} NPSB plus 10 t ha^{-1}farmyard manure fertilizer, which however, was not statistically different from the value (64.42) scored due to combined application of 233 kg ha^{-1} NPSB plus 10 t ha^{-1} of FYM fertilizer. While the lowest value (35.04) was recorded from the control treatment (Table 5).

Increasing rates of NPSB applied from zero to 291 kg ha^{-1} combined with farmyard manure from 0 to 10 t ha^{-1} increased the number of leaves by 85.27 % over the control. Combined use of 291 kg ha^{-1} blended NPSB fertilizer and 10 t ha^{-1} farmyard manure increased leaf number by 61.53 % over 291 kg ha^{-1} blended NPSB fertilizer, 21.71 % over 10 t ha^{-1} farm yard manure. This might be because blended (NPSB) and farmyard manure are rich with nitrogen compound, which enabled the plants to have more number of leaves. In addition, it promotes the plant to grow vegetative, which in turn; the plant might have produced more number of leaves. Many authors reported similar findings on different crops. Joshi (2017) estimated that organic and inorganic nutrients had significant effect on number of leaves per plant of tikhur. Swadija *et al*. (2013) reported significantly the highest number of leaves per plant as a result of application of 10 t ha^{-1} of FYM over absolute control. Odedina *et al.* (2012) also reported significantly the highest number of leaves per plant of cassava root crop due to increasing the levels of inorganic and organic nutrients.

4.2.5 Leaf area

The main effects of Blended (NPSB) and farmyard manure fertilizer on leaf area of Anchote were highly significant ($P< 0.01$) and significant (($P <0.05$), respectively (Appendix Table 2). Similarly, the interaction effect of NPSB and farmyard manure on leaf area was significant ($P< 0.05$). The highest leaf area (156.12cm^2) was scored as the result of combined application of 10 t ha^{-1} FYM plus 291 kg ha^{-1} of NPSB fertilizer, followed by the value (140.28 cm^2) obtained due to combined application of 291 kg ha^{-1} blended NPSB plus 10 t ha^{-1} of farmyard manure fertilizer. Whereas, the lowest leaf area (90.65cm^2) was recorded at 0 t ha^{-1} FYM and 0 kg ha^{-1} NPSB fertilizer, which however, was not statistically different from the value (94.51) obtained due to combined application of 0 t ha^{-1} plus 58 kg ha^{-1} of NPSB fertilizer (Table 5).

Increasing the combined application of blended NPSB and farmyard manure fertilizer from zero to 291 kg ha^{-1} and from zero 10 t ha^{-1}, respectively increased leaf area by 74.39% over the control (Table 4). This might be because blended (NPSB) and farmyard manure are rich with Nitrogen compound, which enabled the plants to have broad leaf size. Moreover, availability of nitrogen in those factors might be the reason for the plant to grow vegetative; in turn the plant might have produced large leaf size as compared with control treatment. This result agrees with finding of Aseffa *et al.* (2016) who reported increase in leaf area of potato as a result of increasing quantity of farmyard manure. This may be due to the nutrient composition of the farm yard manure. It also closely related to the finding of (Najm *et al.*, 2013).

4.1.6 Total biomass

The present study revealed that the main effects of blended (NPSB) and farm yard manure fertilizer highly significantly affected ($P < 0.01$) total biomass of Anchote. Similarly, the interaction effect of blended (NPSB) and farm yard manure was significant ($P < 0.05$) (Appendix Table 2).The highest value (26.30 kg) was scored as the result of combined application of 233 kg ha^{-1} blended NPSB fertilizer plus 10 t ha $^{-1}$ of farmyard manure fertilizer, which, however, was not statistically different from the value (23.91kg) obtained due to combined application 291 kg ha^{-1} + 10 t ha^{-1} of farmyard manure fertilizer. While the lowest value (14.13 kg) was recorded at the control, which, however, was not statistically different from the values (15.93 kg, 16.43 kg and 17.07 kg) obtained as the result of combined application of 116kg ha^{-1} NPSB + 0 t ha^{-1} of farmyard manure, 175 kg ha^{-1} NPSB + 0 t ha^{-1} of farmyard manure and 233 kg ha^{-1} NPSB + 0 t ha^{-1} of farmyard manure fertilizer. The combined use of 233 kg ha^{-1} blended NPSB fertilizer with 10 t ha^{-1}farmyard manure increased total biomass by 86.13%, 36.41% and 32.63% over the control, over higher value of sole application of farm yard manure and over higher value of blended NPSB fertilizer, respectively (Table 5). This study showed that supplying adequate amount of farmyard manure and blended fertilizer to anchote enabled to get more amount of plant biomass during harvesting time. Increased nitrogen fertilizer resulted in increased biomass. This was mainly due to nitrogen source of fertilizers positively influenced vegetative growth of the plant.

The increase in both below and above ground biomass yield might be due to the response of available compounds which have positive effect on vegetative growth and root development. The possible reasons for the highest total biomass observed from the combined application of blended NPSB fertilizer and farm yard manure fertilizer may be related with increase in the nutrients added to the soil. Nutrients in soil and fertilizer applied might have been used efficiently since farm yard manure improves soil chemical and physical property. According to Beji (2017) on sweet potato, increasing P application from 0 to 75 kg N ha^{-1} significantly increased both total and above ground fresh biomass yield by 9.20% and 3.37%, respectively.

Table 5. Interaction effect of applied farmyard manure(t ha^{-1}) and Blended (NPSB kg ha^{-1}) on vine numbers, vine length (m), vine internodes length(cm), number of leaves, leaves area(cm^{2}) and total biomass(kg) of Anchote at Jimma during the 2019 cropping season

Treatment	NPSB	VN	VL	VIL	LN	LA	TBM
FYM	0	2.87^{m}	1.67^{i}	9.89^{j}	35.04^{k}	90.65^{j}	14.13^{i}
	58	2.92^{lm}	1.71^{hi}	11.15^{i}	35.19^{jk}	94.51^{ij}	17.76^{defgh}
0	116	3.23^{kl}	1.99^{gh}	11.28^{i}	36.38^{ijk}	108.93^{gh}	15.93^{ghi}
	175	3.44^{jk}	2.05^{g}	11.39^{i}	38.25^{hij}	128.12^{ef}	16.43^{fghi}
	233	3.59^{jl}	2.06^{g}	11.57^{hi}	39.39^{hi}	124.37^{f}	17.07^{efghi}
	291	3.77^{ghi}	2.07^{fg}	12.24^{gh}	40.19^{hj}	144.78^{bc}	19.83^{cde}
	0	3.91^{fi}	1.68^{i}	12.32^{gh}	40.19^{gh}	94.03^{ij}	18.10^{defgh}
5	58	3.98^{eh}	1.90^{ghi}	12.37^{fgh}	43.28^{g}	97.06^{ij}	15.80^{ih}
	116	3.69^{ghi}	2.47^{de}	12.68^{fg}	47.81^{h}	113.45^{g}	19.15^{cdefg}
	175	4.07^{dg}	2.38^{e}	12.53^{fg}	49.26^{f}	123.16^{f}	19.28^{cdef}
	233	4.10^{def}	2.53^{de}	12.83^{fg}	54.48^{e}	131.97^{def}	19.50^{cdef}
	291	4.19^{c-f}	2.7^{bcd}	13.67^{de}	52.63^{e}	153.40^{ab}	19.80^{dce}
	0	4.25^{cde}	2.34^{ef}	13.76^{cde}	53.34^{e}	89.52^{j}	19.28^{cdef}
	58	4.46^{bc}	2.61^{cde}	13.13^{ef}	55.53^{de}	98.26^{ij}	18.40^{defgh}
10	116	4.44^{bc}	2.51^{de}	13.98^{cd}	58.52^{cd}	101.02^{hi}	20.45^{cd}
	175	4.34^{cd}	2.97^{ab}	14.53^{bc}	61.15^{bc}	135.13^{de}	22.23^{bc}
	233	4.69^{b}	2.86^{abc}	14.92^{b}	62.42^{ab}	140.48^{bc}	26.30^{a}
	291	5.07^{a}	3.00^{a}	15.92^{a}	64.92^{a}	156.12^{a}	23.91^{ab}
$LSD_{0.05}$		0.33	0.28	0.80	3.13	9.59	3.30
$CV_{\%}$		5.10	7.24	3.78	3.87	5.01	10.39

Key. Means sharing common letter(s) are not significantly different at 5% level of significance

4.3 Yield Parameters

4.3.1 Number of storage roots

The analysis of variance revealed that there was no significant difference (P>0.05) due to interaction effect of NPSB blended fertilizer and FYM rates on unmarketable root number of Anchote. The main effects of NPSB blended fertilizer and FYM rate also were non-significant (Appendix Table 3).

4.3.2 Storage root diameter

The analysis of variance showed that the main effect of farmyard manure and blended (NPSB) fertilizer highly significantly (P<0.01) influenced storage root diameter (Appendix Table 3). Interaction of farmyard manure and blended NPSB fertilizer significant (P<0.05) affected the storage root diameter (Appendix Table 3). The highest value storage root diameter (81.94 mm) was scored as the result of combined application of 10 t FYM ha^{-1} plus 175 kg ha^{-1} NPSB fertilizer, which however, was not statistically different from value (76.59 mm), obtained due to combined application of 233 kg ha^{-1}NPSB plus10 t FYM ha^{-1} fertilizer. While the lowest storage root diameter (60.22 mm) was observed at control (Table 6).

Combined application of 175 kg ha^{-1} blended NPSB fertilizer and 10 t ha^{-1} farmyard manure increased storage root diameter by 15.07 % over 291 kg ha^{-1} blended NPSB fertilizer, 23.36 % over 10 t ha^{-1} farm yard manure and by 36.07 % over the control. As the rates of FYM increased the root diameter increased which may be due to the fact that FYM improved the fertility of the soil through decomposition by soil microbes and making nutrients available for uptake and enhancing vegetative growth and partitioning of assimilates in storage roots. Similarly, as the amount of blended fertilizer supply increases the root diameter increases indicating the higher requirement of blended fertilizers for increasing anchote root yield. This might be due to presence of different macro and microelements in blended fertilizer influenced the growth of the root. According to Puzina (2004), using boric acid in potato fertilization caused an increase in tuber size and weight by increasing of cell diameter in the tuber perimedullary zone. For crops that are cultivated for their roots, farmyard manure creates the reduction of soil bulk density so that the roots freely extend to scavenge available nutrients and moisture so that their yield increases significantly (Mujtaba *et al.*, 2013).

4.3.3 Total root weight

The analysis of variance showed that the main effect of blended and farmyard manure fertilizer highly significantly ($P<0.01$) affected average total root weight. Similarly, the interaction of both the fertilizers highly significantly ($P<0.01$) influenced total root weight of anchote (Appendix Table 3).The highest total root weight (0.45 kg) was scored as the result of combined application of 175 kg ha^{-1} of blended NPSB fertilizer plus 10 t ha^{-1} farmyard manure, followed by the result (0.41 kg) obtained due to combined application 233 kg ha^{-1} blended NPSB fertilizer plus 10 t ha^{-1} farmyard manure fertilizer. While the lowest was recorded from the control (0.31 kg) (Table 6).

Increasing the rate of combined application of blended NPSB and farm yard manure fertilizer from 0 to 175 kg ha^{-1} and 0 to 10 t ha^{-1} enabled to increase total root weight by 45.16% over the control 28.57% over farmyard manure and by 28.57% over blended NPSB fertilizer (Table 6). The main reason for the variation among the treatments was that blended NPSB and farm yard manure fertilizer is rich in organic matter which influences the yield of the crop. In addition, besides of heavy feeder characteristics of the anchote, availability of different nutrients in both factors may make the root to grow highly.

The increase in the weight of roots with the supply of fertilizer nutrients could be due to more luxurious growth, more foliage and leaf area and higher photosynthetic rate that extends the canopy life which subsequently prolong the duration of tuber bulking and ensure production of bigger tubers (Zewudie *et al.*, 2012). The increased application rate of combined use of Cattle manure and mineral NP from 0-7.5 t CM with 75% RDF ha^{-1} increased average tuber weight by 23.08 and 29.68% as compared to the control in both Belg and Meher season respectively (Zewudie *et al.*, 2018). According to Bari *et al.* (2001), the application of 1.1 kg B/ha from borax increased potato fresh haulm weight/hill.

4.3.4 Total root yield

The analysis of variance revealed that total root yield of anchote was highly significantly ($P<0.01$) affected by the main effect of blended (NPSB) and farm yard manure fertilizer. Similarly, the interaction effect was significant ($P<0.05$) (Appendix Table 3). The highest total root yield (29.78t ha^{-1}) was scored as the result of combined application of 175 kg ha^{-1} blended NPSB fertilizer plus 10t FYM ha^{-1} farmyard manure fertilizer, which ,however, was not statistically different from the value (27.42 t ha^{-1}) obtained due to combined application of 233 kg ha^{-1} blended NPSB plus 10 t ha^{-1} farmyard manure fertilizer. While the lowest value (15.85 t ha^{-1}) was recorded from the control, which ,however, was not statistically different from the values (16.62 t ha^{-1},17.34 t ha^{-1},18.66 and 18.09) scored as the result of combined application of 58 kg ha^{-1} blended NPSB plus 0 t ha^{-1} farm yard manure, 116 kg ha^{-1} blended NPSB plus 0 t ha^{-1} farmyard manure, 175 kg ha^{-1} blended NPSB plus 0 t ha^{-1} farmyard manure and 291 kg ha^{-1} blended NPSB plus 0 t ha^{-1} farmyard manure fertilizer respectively (Table 6). This lowest value might be scored due to shortage of nutrient applied to the soil that needed for proper growth and development of the yield.

The highest yield response with highest rate of combined application of blended NPSB and farm yard manure might be due to an initial fast release of nutrients to plants from the inorganic fertilizer, prior to the release of nutrients from the organic sources, thereby, solving the characteristic shortcoming of slow initial release of nutrients from sole organic manure application (Ayoola and Makinde, 2008).This result corroborates with the finding of (Boru, 2017), who reported that application of 15 t FYM ha^{-1} + 69 kg P_2O_5 ha^{-1} fertilization enabled maximum potato tuber yield per hectare. According to Abera and Gudeta (2007) the increment of nitrogen supply from 0 to 46 kg ha^{-1}resulted in an increase of 20% root yield and then afterwards declined. Apart from that, it was similar with (Mohamed *et. al*.2018) in potato stated that integration of different rates of inorganic fertilizers (NP) with various rates of organic manures (FYM) showed a significant effect on both marketable and total tuber yield; whereas, unmarketable yield was statically not significantly.

Zewide *et al.* (2012), also reported on potato that total tuber yield was highly significantly influenced by nitrogen and phosphorus. Inorganic phosphorus applied might have supplemented the low phosphorus in the applied FYM which increased its availability in the soil. Asieku *et al.* (2015), also reported that combined application of organic and inorganic fertilizer gave significantly higher total yiel5d of tuber of white yam.

4.3.5 Harvest index

The analysis of variance showed that the main effects of FYM and blended NPSB fertilizer highly significantly ($P<0.01$) affected harvest index. The interaction effect was also significant ($P<0.05$) (Appendix Table 3). The highest harvest index (82.86%) was scored as the result of combined application of 10 t ha^{-1} FYM plus175 kg ha^{-1} fertilizer, which, however, was not statistically different from the values (80.50% and 79.91%) obtained as due to combined application of 233 kg ha^{-1} blended NPSB plus 10 t ha^{-1} farmyard manure and 291 kg ha^{-1} blended NPSB plus 10 t ha^{-1} farmyard manure fertilizer respectively (Table 6). Whereas the lowest (52%) was recorded at from the control. Due to combined application of 175 kg ha^{-1} of blended NPSB and 10 t ha^{-1} of farm yard manure harvest index was raised by 59.34%, by 31.19 % and by 11.67% over the control, over blended NPSB and over farmyard manure fertilizer respectively (Table 6).

The highest harvest index at the highest rate of FYM and blended (NPSB) fertilizer may be as FYM and blended fertilizer in combination is good enhancer of soil fertility by adding essential nutrients in available form for plant uptake for better vegetative growth. As well as, the blended fertilizer NPSB used was enriching of essential nutrients required plant growth in both below and above the ground parts. Similar finding was described on potato by (Bekalo, 2017) who reported harvest index was increased by 15 and 16 % due to application of FYM alone and combined half FYM and blended fertilizer over the control

Table 6.The interaction effect of NPSB Kg ha^{-1} and FYM t ha^{-1} fertilizer on number of, storage root diameter (mm), total root weight (kg), total root yield (t ha^{-1}) and harvest index(%) of anchote at Jimma during growing season of 2019.

Treatments FYM	NPSB	SRD	TRW	TRY	HI
	0	60.22^{a}	0.31^{j}	15.85^{h}	52.00^{j}
	58	63.38^{ef}	$0.33i^{h}$	16.62^{h}	54.04^{ij}
0	116	64.24^{ef}	0.34^{ghi}	17.34^{h}	58.41^{hij}
	175	67.92^{cde}	0.33^{ih}	18.66^{gfh}	61.76^{ghi}
	233	72.25^{bc}	0.37^{de}	21.19^{def}	70.08^{efg}
	291	71.21^{bcd}	0.35^{fgh}	18.09^{gh}	63.18^{fgh}
	0	63.48^{ef}	0.32^{ij}	20.79^{efg}	62.11^{ghi}
	58	71.81^{bcd}	0.33^{igh}	21.32^{def}	70.67^{edf}
5	116	65.51^{ef}	0.34^{igh}	22.993^{cde}	71.19^{def}
	175	72.48^{bc}	0.35^{fg}	22.79^{de}	72.65^{bcde}
	233	73.87^{b}	0.36^{ef}	23.19^{cde}	73.37^{bcde}
	291	71.37^{bcd}	0.37^{de}	23.83^{cd}	61.38^{hi}
	0	66.42^{ed}	0.35^{fg}	23.82^{dc}	74.20^{bcde}
	58	71.15^{bcd}	0.36^{fe}	22.23^{de}	79.06^{abcd}
	116	74.78^{b}	0.38^{cd}	22.81^{de}	71.71^{cde}
10	175	81.94^{a}	0.45^{a}	29.78^{a}	82.86^{a}
	233	76.59^{ab}	0.41^{b}	27.42^{ab}	80.50^{ab}
	291	73.94^{b}	0.39^{c}	25.73^{bc}	79.91^{abc}
LSD (*0.05*)		5.48	0.02	2.81	8.42
CV (%)		4.52	3.18	7.54	7.17

Key. Means sharing common letter(s) are not significantly different at 5% level of significance.

4.4 Quality Parameters

4.4.1 Tuber dry matter (%)

The Analysis of variance showed that root dry matter content was highly significantly (P<0.01) affected by both blended NPSB and farm yard manure fertilizer. Likewise, the interaction of these two nutrient sources significantly (P<0.05) affected root dry matter content of anchote (Appendix Table 4) .The highest tuber dry matter content (28.45%) was scored as the result of combined application of 233 kg ha^{-1} NPSB plus 10 t ha^{-1} farmyard manure fertilizer, followed by the value (25.75%) obtained due combined application of 291 kg ha^{-1} of blended NPSB plus 10 t ha^{-1} of FYM fertilizer (Table 7) .While the lowest root dry matter content (17.37 %) was recorded at the control, which however, was not statistically different from the value (18.34%) obtained as the result of combined application of 58 kg ha^{-1} blended NPSB plus 0 t ha^{-1} farmyard manure fertilizer (Table 7).

The highest value of root dry matter content of the treated plot was exceeded the value of control, blended NPSB and FYM fertilizer by 63.73%, 30.44% and 18.59% respectively. In like manner, increasing the varying rates of farmyard manure from zero to 10 t $ha^{-1}$was enabled to enhance root dry matter by 25.94%. Likewise, increasing application rates of NPSB blended fertilizer from zero to 233 kg ha^{-1} made to increase root dry matter by15.96%.

The possible reason for the highest root dry matter content observed at treated plot may be associated with application of inorganic and organic fertilizer have positive influence on root enlargement that enables the crop to have more dry matter. In addition to that the dry matter of the root may also increase as compared with untreated plot. According to Naz *et al.* (2011), dry matter contents increased with increase in NPK. Ababulgu (2018) also reported that the main effect of NPS blended fertilizers and cattle manure significantly influenced dry matter content of tuber of potato. Yahaya *et al.* (2012) also reported that the application of the fertilizers enhanced the accumulation of dry matter in white yam.

4.4.2 Ash content

The analysis of variance revealed that the tuber ash content was highly significantly (P<0.01) affected by both blended NPSB fertilizer and Farm yard manure. Likewise, the interaction of these two factors was highly significant (P<0.01) (Appendix Table 4). The highest ash percentage (5.21%) was scored as the result of combined application of 233 kg ha^{-1} of blended (NPSB) plus 10 t ha^{-1} of farmyard manure fertilizer, which however, was not statistically different from the values (5.14% and 4.91 %) obtained due to combined application of 175 kg ha^{-1} of blended NPSB plus 10 t ha^{-1} of FYM and 291 kg ha^{-1} blended NPSB and 10 t ha^{-1} farmyard manure fertilizer respectively. While the lowest (3.35%) was observed at 0 kg of NPSB plus 5 t ha^{-1} of FYM fertilizer, followed by the value (3.68%) obtained due to combined application of 58 kg of NPSB plus 5 t ha^{-1} of FYM fertilizer (Table 7).

The result obtained confirms that application of organic and inorganic to the crop enhance availability of ash in that crop. This might be due to blended NPSB and FYM fertilizer have different elements which can absorbed by the crop. The possible reason for the increase of ash content with the application of blended NPSB fertilizers with combination of FYM might be presence of inorganic phosphorous in both factors which enables better development of root system and FYM improves the structure of the soil that enables the root to grow freely and possibly higher penetration in the soil. So, it may have enabled in absorption of different minerals nutrients from the soil.

Similar finding was given on sweet potato variety by Gemechu (2018) that identified ash content in sweet potato variety) kulfo increased from 4.47 to 5.11% as NPSB increased from 0 to 239 kg ha^{-1} .According to Ezeocha *et al*. (2014), ash content was significantly affected by poultry manure application. Ash content ranged from 3.41– 4.68 % with 4 t/ha level of poultry manure application having the highest ash content.

4.4.3 Moisture content

The result of analysis of variance showed that the main effects of blended NPSB and farmyard manure fertilizers highly significantly ($P<0.01$) affected moisture content of anchote Similarly, the interaction of farmyard manure and blended NPSB fertilizer also highly significantly ($P<0.01$) affected moisture content of anchote **(**Appendix Table 4). The highest value (8.2%) was scored at the control treatment, followed by the value (8.03%) scored due to combined application of 58 kg ha^{-1} plus 0 t ha^{-1} FYM fertilizer (Table 7). Whereas the lowest value (4.4%) was obtained from combined application 291 kg ha^{-1}NPSB plus 10 t ha^{-1}

FYM fertilizer, followed by the value (4.57%) scored as the result of combined application of 233 kg ha^{-1}of NPSB plus 10 t ha^{-1} of FYM fertilizer (Table 7). Due to combined application of blended NPSB and farmyard manure fertilizer moisture content of anchote changed by 86 % as compared to control, 7.89% farmyard manure and 20% blended NPSB fertilizer. This is most probably because both organic and inorganic fertilizers applied were adequate with nutrient like phosphorous that increased root enlargement and which in turn increased root dry matter of the crop which might have negatively influenced moisture content of the crop. A similar finding was reported on aerial yam by (Ezeocha, 2014) who stated that moisture content of aerial yam was inversely proportional to dry matter.

4.4.4 Total soluble solid (^{0}B)

Total soluble solids content in the bulb is an important quality parameter (Singh ,2015).The analysis of variance showed that the effect of blended (NPSB), farmyard manure and the interaction of both factors were highly significantly ($P<0.01$) affected the TSS of anchote root (Appendix Table 4).The highest value (8.67^0 brix) of TSS was scored as the result of combined application of 233 kgha^{-1} plus 10 t ha^{-1} of farmyard manure fertilizer, which, however, was not statistically different from the value (8.35^0 brix) obtained due to combined application of blended NPSB 291 kg ha^{-1} plus 10 t ha^{-1} of FYM fertilizer (Table 7). Similar fashion, this value was enhanced by 27.5% over the control, by 7.97% over farmyard manure and by 14.08%over blended NPSB fertilizer. While the lowest value (6.8^0 brix) was observed at control treatment, which, however, it was not statistically different from the value (7.15^0 brix) scored due to combined application of 58 kg ha^{-1} NPSB plus 5 t ha^{-1} of FYM fertilizer (Table 7).

This finding showed that blended fertilizer highly influences total soluble solid of the crop. The possible reason for the increase of TSS content with the application of blended NPSB fertilizers with combination of FYM might be more utilization of inorganic nitrogen in both factors which enables better development of root system and possibly higher synthesis of plant growth hormones. So, it may have helped in increasing the sugar content of the root. In addition, presence inorganic sulphur in blended and FYM fertilizer might be influenced amino acids in the root.

Different authors on different crop obtained closely related results. Singh (2015) reported on onion that all the integrated nutrient management treatments significantly influenced the total soluble solids. Agrawal *et al*. (2017) reported that total soluble solid of tuber increased as the source of K fertilizer dose increased. The highest TSS content in root might be due to maximum moisture content and dry weight of root because organic fertilizers carry almost all micro and macro nutrients that are required for the plants growth (Agrawal *et al*., 2017).

4.4.5 Crude fat

The Analysis of variance showed highly significant ($P<0.01$) variation in crude fat content due to main effect of blended NPSB and farmyard manure fertilizer. On the other hand, the interaction effect of both fertilizer were also highly significant ($P<0.01$) (Appendix Table 4). The highest crude fat was (2.12%) was scored at control treatment, followed by the value (1.75%) scored as the result of combined application 58 kg ha^{-1} NPSB plus 0 t ha^{-1} of FYM fertilizer (table 7). While the lowest (0.56%) was recorded due to combined use of 291kg ha^{-1} of blended NPSB plus 10 t ha^{-1}farmyard manure fertilizer, which, however, was not statistically different from the value (0.73%) scored as the result of combined application of 291 kg ha^{-1} NPSB plus 10 t ha^{-1} of FYM fertilizer (Table 7).

The combined use of 291 kg ha^{-1} plus 10 t ha^{-1}fertilizer was a reason for varying of crude fat by 73.58% as compared to control 33.96% farmyard manure and 29.25% blended NPSB fertilizer. In a like manner, increasing the varying rates of farmyard manure from zero to 10 t $ha^{-1}$was enabled to deduct crude fat by 42.51%. This was most probably obtained due to the effect of blended NPSB and FYM fertilizer applied during experiment might be negatively influence formation of fat in the root and nitrogen present in both treatments might be reason for deduction of crude fat in anchote root. The finding indicates, even though, it is inconsistence inorganic and organic substance has influence on crude fat content of root crops. This finding is similar with Nazi *et al.* (2011) who demonstrated that enhancing the amount of fertilizer reduced crude fat of potato. It was also closely similar with the finding of Kareem (2013), who stated that the highest crude fat production was recorded from control plots while all the fertilizer treated plots (that is organic, inorganic and organo-mineral fertilizers) had the same percentage of 0.96, which is lower than the control.

Table 7.Interaction effect of Blended (NPSB) and farmyard manure on total dry matter content Ash, Total Soluble Solid, Crude fat and moisture content of Anchote at Jimma during growing season of 2019.

Treatments FYM t ha^{-1}	NPSB Kha^{-1}	RDM%	ASH	TSS	CF	MO
	0	17.37^{k}	4.25^{fg}	6.80^{h}	2.12^{a}	8.2^{a}
	58	18.34^{jk}	4.43^{def}	8.05^{bcde}	1.75^{bc}	8.03^{b}
	116	21.16^{hi}	4.52^{cdef}	8.00^{bcde}	1.68^{bcd}	7.77^{c}
0	175	20.03^{ji}	4.55^{cdef}	7.63^{defg}	1.55^{cdef}	7.68^{c}
	233	22.28^{fgh}	4.58^{cde}	7.55^{feg}	1.43^{efg}	7.34^{d}
	291	21.77^{ghi}	4.6100^{bcd}	8.15^{abcd}	1.50^{defg}	7.00^{e}
	0	22.56^{efgh}	3.35^{i}	7.77^{cdef}	1.49^{defg}	6.90^{e}
	58	22.64^{defgh}	3.68^{h}	7.15^{fgh}	1.18^{hij}	6.25^{f}
	116	22.89^{defgh}	4.05^{g}	8.43^{ab}	1.63^{bcde}	6.10^{gf}
5	175	23.24^{defg}	4.26^{efg}	7.35^{fgh}	1.85^{b}	5.96^{gh}
	233	23.38^{defg}	4.63^{bcd}	8.00^{bcde}	1.61^{cdef}	5.90^{h}
	291	23.64^{cdefg}	4.72^{g}	7.60^{defg}	1.28^{ghi}	5.73^{i}
	0	23.98^{bcdf}	4.03^{g}	7.60^{defg}	1.40^{fgh}	5.40^{j}
	58	24.28^{bcde}	4.50^{cdef}	8.00^{bcde}	1.16^{ij}	5.37^{j}
	116	24.57^{bcd}	4.80^{bc}	7.58^{defg}	1.02^{kj}	526^{kj}
10	175	25.38^{bc}	5.14^{a}	8.03^{bcde}	0.89^{kl}	5.10^{k}
	233	28.44^{a}	5.21^{a}	8.67^{a}	0.73^{lm}	4.57^{l}
	291	25.75^{b}	4.91^{ab}	8.35^{abc}	0.56^{m}	4.40^{m}
	LSD (0.05)	1.97	0.33	0.59	0.23	0.15
	CV (%)	5.20	4.18	4.41	10.25	1.38

CV: Coefficient of variations; LSD; Least significance difference: means sharing common letter(s) are not significantly different at 5% level of significance.

4.5 Post Harvest Soil Chemical Properties

Post harvest soil chemical properties were analyzed for 18 treatments .The results were compared to different scholar's recommendation. Scianna *et al.* (2007) classified soil acidity on the bases of crop tolerance and performance as ultra-acidic (pH< 3.5), extremely acidic (pH=3.5 - 4.4), very strongly acidic (pH=4.5-5.0), strongly acidic (pH=5.1- 5.5), moderately acidic (pH=5.6 - 6.0), slightly acid (pH=6.1- 6.5),neutral (pH = 6.6 - 7.3), slightly alkaline (pH = 7.4 - 7.8), moderately alkaline (pH = 7.9 - 8.4),strongly alkaline (pH = 8.5 - 9.0), and very strongly alkaline (pH > 9.0). Landon(2014) classified soils having total N of greater than 1.0% a very high, 0.5 - 1.0% high, 0.2 - 0.5% medium, 0.1 - 0.2% low and less than 0.1% as very low in total nitrogen content. Karltun *et al.* (2013) described soils with available P content of <15 ppm as very low. The Netherlands commissioned study by Ministry of

Agriculture and Fisheries (1985) classified soil with organic carbon contents (%) >3.50, 2.513.5, 1.26-2.50, 0.60 - 1.25 and <0.60 as very high, high, medium, low and very low respectively. Depending on that catagorision, the following soil chemical properties were analyzed.

4.5.1 Soil pH and cation exchange capacity (meq/100g)

The highest soil pH value (6.88) was observed at the treatment that treated by 291 kg ha^{-1} blended NPSB plus 10 t ha^{-1}farm hard manure fertilizer in a combination form. This was equal with the value obtained from the treatment that received 233 kg ha-1blended NPSB plus 10 t ha^{-1} farmyard manure fertilizer. On the other hand, the lowest pH value (6.03) was recorded form the control treatment. The pH values of all treatments are less than the pH value of farm yard manure (7.43) and greater than the pH value initial soil (5.5) (Appendix Table 6). Therefore, the result obtained shows that the application of organic and inorganic fertilizer has positive effect on decrease of soil acidity.

The highest soil cation exchange capacity (CEC) value (30.76) was obtained by combined application of 291kgha^{-1} blended NPSB fertilizer plus 10 tha^{-1} FYM followed by three treatments 233kgha^{-1} blended NPSB fertilizer plus 10 tha^{-1} FYM, 175kgha^{-1} blended NPSB fertilizer plus 10 tha^{-1} FYM and 116kgha^{-1} blended NPSB fertilizer plus 10 tha^{-1} FYM that have equal value of (30.39). Apart from that, the lowest CEC value (24.57) was scored at control treatment. CEC values of all treatments are less than CEC value of FYM (115.42) (Appendix Table 7).Hence the result obtained showed FYM have more positive effect than blended NPSB fertilizer with regard to increasing CEC. The current finding is in agreement with that of Hailu *et al.(*2014) who reported that application of organic matter as soil amendment resulted in positive and significant increase in soil chemical properties such as soil pH and cation exchange capacity (CEC). Hota *et al*. (2014) also identified that application of NPK alone showed decreasing trend of pH, whereas integrated use of inorganics and organic sources considerably improved the soil pH.

4.5.2 Soil organic carbon (%) and organic matter (%)

The highest soil organic carbon (OC) value (3.16) was obtained from combined application of 291kgha^{-1}blended NPSB fertilizer and 10 t ha^{-1} farm yard manure and combined application of 233kgha-1blended NPSB fertilizer and 10 t ha^{-1} farm yard manure. On the other hand, the lowest organic carbon value (2.457) was recorded from the control treatment. Organic carbon results of all treatments increases as rates of farm yard manure and blended NPSB increases. (Appendix Table 6).Since FYM has high OC value (31.68) it may have direct effect organic carbon results of each treatment. On other hand, the highest organic matter (OM) value (5.45) was recorded from the combined application of 291kg ha^{-1} plus 10 t ha^{-1} farm yard manure fertilizer. Similarly, the lowest value (4.23) was obtained from the control treatment. Since the value of organic matter available in farm yard manure was greater that the value of organic matter in all treatments the variation formed thought to due to application of farm yard manure fertilizer. Addition of organics along with inorganic showed significant improvement in total N content of the soils (Hota *et al.*, 2014).In the present study, OM application to soil increased soil pH, phosphorus availability, cation exchange capacity (CEC) and soil organic carbon content(Deb *et al.*, 2016).

4.5.3 Soil total nitrogen (%) and available phosphorus (ppm)

The highest soil total nitrogen (TN) result (0.272) was recorded due to combined application of 291kgha^{-1}blended NPSB fertilizer plus 10 t ha^{-1} farm yard manure , combined application of 233 kgha^{-1}blended NPSB fertilizers and 10 t ha^{-1} cattle manure and combined application of 175 kgha^{-1}blended NPSB fertilizers and 10 t ha^{-1} farm yard manure. Apart from that, the lowest TN value (0.22) was recorded from the control treatment. Total nitrogen result of all treatments was much less than total nitrogen values of farm yard manure (2.73) (Appendix Table 6). The laboratory values of treatments show that numeric variation is small with different levels of farm yard manure relative to different level of blended NPSB fertilizer. This may be due to limited availability of nitrogen from farm yard manure and free availability of nitrogen from blended NPSB fertilizer.

The highest soil available phosphorus value (35.63) was revealed as the result of combined application of 291kgha^{-1}blended NPSB fertilizer plus 10 t ha^{-1} farm yard manure (FYM). Otherwise, the lowest available phosphorus value (15.1) was revealed from the control treatment. Available phosphorus values of all treatments were much less than available phosphorus value of farm yard manure (2223.79) fertilizer (Appendix Table 6).The laboratory values of treatments showed that numeric variation is small with different level of blended

NPSB fertilizer relative to different level of farm yard manure. This may be readily availability of phosphorus from farm yard manure as it is found in inorganic form. Biederman and Harpole (2013) reported that the addition of organic matter to soils resulted, increased soil phosphorus (P), total soil nitrogen (N) and total soil carbon (C). Phosphorus and potassium in manure are mostly present in the inorganic form.

4.6 Pearson's correlations of Growth, Yield and Quality Variables

Estimates of correlation coefficients between each pair of characters are presented in Table 9. Accordingly, positive and highly significant correlations, positively and negatively, were observed between most of the growth and yield characters (Table 8). Leaf number was highly significant positively VIL (r= 0.90**), VL (r=0.89**), LA (r=0.42**),TBM(r=0.72**), HI (r=0.78**), SRD (r=0.67**), SRW (r=0.76**), TRY (r=0.83**), DPM (r=0.86**), TDM(r=0.83**), TSS(r=0.36**), ASH (r=0.49**) and highly significant negatively correlated to CF (r=-0.75**)(Table.8).Vine number was highly significant positively correlated to VIL(r=0.86**),VL (r=0.72**),LA(r=0.42**),TBM(r=0.67**), HI (r=0.76**), STD(r= 0.61**), SRW (r=0.64**), TRY (r=0.74**), DPM (r=0.82**), TDM (r=0.83**) , significant to positively to ASH (r = 0.32*) and highly significant negatively CF (r=-0.81**)(Table 9). Vine Internode length was highly significant positively correlated to VL (r=0.86**), LA(r=0.47**), TBM (r=0.78**),HI (r=0.72**), SRD(r=0.65**) , SRW (r=0.73**), TRY (r=0.77**), DPM (r=0.83**), TDM (r=0.84**), TSS (r=0.41**),ASH(r =0.42**) and highly negatively to CF (r = -0.80**)Table 8). Vine length was highly significant positively correlated to LA (r=0.57**), TBM (r=0.71**), HI (r=0.72**), SRD (r=0.69**) , SRW (r=0.78**), TRY (r=0.79**), DPM (r=0.83**), TDM (r=0.75**), TSS (r=0.41**), ASH (r =0.59**), positively significantly correlated to TSS(r=0.34*) and highly negatively to CF (r = -0.66*) Table 8) Leaf area was highly significant positively correlated to TBM(r=0.51**), SRD (r= 0.53**), SRW (r=0.56**), TRY (r=0.42**), DPM (r=0.60**), TDM (r=0.42**), TSS (r=0.0.38**), ASH (r = 0.62**) , highly significantly negative CF(r=-0.42**) (Table 8).Total biomass was highly significant positively correlated to HI (r=0.55**), SRD(r=0.52**), SRW (r=0.66**), TRY (r=0.64**), DPM (r=0.69**), TDM (r=0.67**), TSS(r=0.86**) ,ASH (r=0.51**) and negatively highly significant CF(r=-0.63**) (Table 8).

Harvest index was highly significant positively correlated to STD (r= 0.67**), SRW (r=0.66**), TRY (r=0.76**), DPM (r=0.69**), TDM (r=0.79**) and positively significant to ASH (r=0.32*) and negativity highly significant to CF(r = -0.65**) (Table 8). Storage Root diameter was highly significant positively correlated to SRW (r=0.76**), TRY (r=0.68**), DPM (r=0.74**), TDM (r=0.65**), ASH (r=0.54**) and negativity highly significant to CF(r = - 0.61**) (Table 9). Storage root weight was highly significant positively correlated to TRY (r=0.77**), DPM (r=0.78**), TDM (r=0.69**), TSS (r=0.36**), Ash (r=0.68**) and negativity highly significant to CF (r= -0.33**) (Table 8). Total root yield was highly significant positively correlated to DPM (r=0.83**), TDM (r=0.80**), Ash (r=0.36**) and negativity highly significant to CF(r= -0.66*) (Table 8).Days of physiological maturity was highly significant positively correlated to TDM (r=0.77**), Ash (r=0.56**) and positively significant to TSS (r=0.30*) and negativity highly significant to CF (r= -0.67**) (Table 8). Total dry matter was positively significant to TSS (r=.0.37*), ASH (r=0.39*) and negativity highly significant to CF (r= -0.74**) (Table 8). Ash was negatively highly significant to CF(r =- 0.43**) (Table 8).Therefore, application of Blended (NPSB) and farm yard manure fertilizer had a significant influence on growth and yield attributes of anchote.

Table 8.Pearson's Correlations of growth, yield and quality variables in interaction of farm yard manure and NPSB blended fertilizer

Pearson's Correlation Coefficients, N = 54

Prob > |r| under H0: Rho=0

Variables	VN	LN	VIL	VL	LA	TBM	HI	SRD	**SRW**	TRY	DPM	TDM	**TSS**	ASH	CF
VN	1	0.89**	0.86**	0.72**	0.42**	0.67**	0.76**	0.61**	0.64**	0.74**	0.82**	0.83**	0.33*	0.32*	-0.81**
LN		1	0.90**	0.89**	0.42**	0.72**	0.78**	0.67**	0.76**	0.83**	0.86**	0.83**	0.36**	0.49**	-0.75**
VIL			1	0.86**	0.47**	0.78**	0.72**	0.65**	0.73**	0.77**	0.83**	0.84**	0.41**	0.42**	-0.80**
VL				1	0.57**	0.71**	0.72**	0.69**	0.78**	0.79**	0.83**	0.75**	0.34*	0.59**	-0.66**
LA					1	0.51**	0.30*	0.53**	0.51**	0.42**	0.60**	0.42**	0.38**	0.62**	-0.42**
TBM						1	0.55**	0.52**	0.66**	0.64**	0.69**	0.67**	0.57**	0.51**	-0.63**
HI							1	0.67**	0.66**	0.76**	0.69**	0.79**	0.27ns	0.32*	-0.65**
SRD								1	0.76**	0.68**	0.74**	0.65**	0.19ns	0.54**	-0.61**
SRW									1	0.77**	0.78**	0.69**	0.36**	0.68**	-0.70**
TRY										1	0.81**	0.80**	0.26^{ns}	0.36**	-0.66**
DPM											1	0.77**	0.30*	0.56**	-0.67**
TDM												1	0.37**	0.39**	-0.74**
TSS													1	0.14^{ns}	0.05^{NS}
ASH															-0.43**
CF															1

*ns = non significant, ** = significant at 1% ,* = significant at 5 %,VN =vine number, LN = leaf number, VIL =vine internode length,VL =vine length, = LA = leaf area, TBM= total biomass, HI =harvest index, SRD=storage Root diameter, =SRW = storage Root weight, TRY = total Root yield, DPM = days of physiological maturity, TDM = total dry matter, TSS=total soluble solid, ,ASH and CF = crude fat*

4.7 Partial Budget Analysis

Partial budget was analyzed for average of 18 treatment combinations. The recommended level of 10% was reduced from all treatments to obtain net yield.Net yield was multiplied by the market price to obtain gross field benefit. Costs and benefits were calculated for each treatment. It resulted in highest gross income and net benefit in interaction of 10 t ha^{-1} farm yard manure with 175 kg ha^{-1} blended (NPSB) fertilizer with an acceptable marginal rate of return (MRR) 337.32%(Table 9).Accordingly, the highest net benefit was obtained from the interaction of farm yard manure with 10 t ha^{-1} and blended (NPSB) fertilizer 175 kg ha^{-1} was 23532.2 ETB ha^{-1} (Table 9).

Due to this doze of fertilizer applied in combined form 7840.7 ETB ha^{-1} was generated over the control ,2,750.4 ETB ha^{-1} over alone application of 10 t farm yard manure ha^{-1} and 10861.1 ETBha^{-1} over alone application of 291 kg blended NPSB ha^{-1}. Apart from that, the next highest net benefit was 20781.8ETB ha^{-1} which was reduced by 2750.4 ETB ha^{-1} from the highest net benefit. On the other hand, the highest MRR was obtained from the treatment that treated by 175 kg ha^{-1} blended NPSB along with 10 t ha^{-1} of farm yard manure fertilizer, with net benefit of birr 23532.2 ETB ha^{-1}.Therefore it was obtained from the same treatment combination.

Based on yield and yield related variables, positive response was observed in the interaction of 175kg ha^{-1} NPSB blended NPSB fertilizer and 10 t ha^{-1} farm yard manure rate. Therefore, this rate was recommended in addition to highest net benefit and marginal rate of return from the tested experiment.

Table 9.The economic analysis results of NPSB and FYM fertilizer combination in Anchote grown at Jimma in 2019 growing season.

Treatments				GFB		HTC	TVC	NB	MRR (%)
NPSB	FYM	TTY/Tha-1	ARY	(ETBha-1)	FC	ETB/ton	ETB/ton	ETB/ha	
0	0	15.85	14.265	226.100	0	1426.5	1426.5	15691.5	__
58	0	16.62	14.958	248.60	1044	1495.8	2539.8	15409.8	D
116	0	17.34	15.606	270.608	2088	1560.6	3648.6	15078.6	D
175	0	18.66	16.794	313.38	3150	1679.4	4829.4	15323.4	D
233	0	21.19	19.071	404.11	4194	1907.1	6101.1	16784.1	114.86
291	0	18.09	16.281	294.52	5238	1628.1	6866.1	12671.1	D
0	5	20.79	18.711	389.00	1400	1871.1	3271.1	19182.1	D
58	5	21.32	19.188	409.08	2444	1918.8	4362.8	18662.8	D
116	5	22.99	20.691	475.68	3488	2069.1	5557.1	19272.1	51.02
175	5	22.79	20.511	467.4457	4550	2051.1	6601.1	18012.1	D
233	5	23.19	20.871	483.9985	5594	2087.1	7681.1	17364.1	D
291	5	23.83	21.447	511.082	6638	2144.7	8782.7	16953.7	D
0	10	23.82	21.438	510.6532	2800	2143.8	4943.8	20781.8	D
58	10	22.23	20.007	444.7556	3844	2000.7	5844.7	18163.7	D
116	10	22.81	20.529	468.2665	4856	2052.9	6908.9	17725.9	D
175	10	29.78	26.802	798.1636	5950	2680.2	8630.2	23532.2	337.32
233	10	27.42	24.678	676.6708	6994	2467.8	9461.8	20151.8	D
291	10	25.73	23.157	595.8296	8038	2315.7	10353.7	17434.7	D

TRY= Total root yield, ARY (10%) =Adjusted root yield, GFB= Gross field benefit, FC= Fertilizer cost (which includes preparation, transporting and application cost) HTC= Harvesting and transport cost, TVC= Total variable cost, NB= Net benefit MRR=Marginal Rate of Return (%), ETB=Ethiopian Birr, D = Dominated.

5. SUMMARY AND CONCLUSION

The results of the study showed that growth, yield and quality parameters of anchote such as emergence percentage, days to physiological maturity, vine number, vine length, leaf number, vine inter-node length, leaf area, total biomass, total storage root yield, storage root weight, storage root diameter (mm), harvest index, dry matter content and TSS increased as a result of the application of NPSB blended fertilizer and farm yard manure rates.

The highest and lowest mean values of vine length (3.00 and 1.67m), leaf area (156.12 and 90.65cm^2), vine number (5.07 and 2.87), leaf number (64.92 and 35.04) and vine internode length (15.92 and 9.89 cm) were recorded at 291 kg NPSB ha^{-1} and 10 t FYM ha^{-1} and control treatment respectively. Application of 233kg NPSB ha^{-1} plus 10 t FYM ha^{-1} gave the highest total biomass 26.30 kg while the lowest value 14.13 kg was obtained from the control. Application of blended NPSB 175 kg ha^{-1} in combine with 10 t FYM ha^{-1} enabled to get highest yield and yield component variables. The highest root diameter (81.94 mm) was obtained by combined application of 175 kg blended NPSB ha^{-1} with 10 t FYM ha^{-1}fertilizer. While, the least root diameter (60.22mm) was observed at control. Similarly, the highest total root yield (29.78t ha^{-1}and the Lowest (15.85t ha^{-1}), highest total root weight (0.45 kg) and the lowest (0.31kg) ,was recorded for 233kg NPSB ha^{-1} plus 10 t FYM ha^{-1}and at control level respectively. While the highest harvest index (82.86%) and the lowest (52.00%) was recorded for 175 kg NPSB ha^{-1} plus 10 t FYM ha^{-1}and at control level respectively.

The interaction of both fertilizers was influenced quality of Anchote root at different rates. The highest total dry matter (28.45 %) was formed due to combined application of 233 kg ha^{-1} of blended NPSB plus 10 t ha^{-1} farmyard manure fertilizer and the lowest (17.37 %) was observed at control. The highest TSS (8.67 ^{0}brix) was observed at combined application of 233 kg ha^{-1}blended NPSB plus 10 t ha^{-1} of farm yard manure fertilizer and the lowest (6.8 ^{0}brix) was observed at the control. The highest ash (5.21%) was recorded at interaction effect of 233kg NPSB ha^{-1} plus 10 t FYM and the lowest (3.35%) was recorded at the control. Highest moisture (8.20%) and the lowest (4.40%) was recorded from control treatment and interaction effect of 291kg NPSB ha^{-1} plus 10 t FYM respectively. Highest crude fat 2.12%) and the lowest (0.56 %) was recorded at the control and interaction effect of 291 NPSB kg ha^{-}

^{1} plus 10 t FYM ha^{-1} fertilizer respectively. The main effects of NPSB blended fertilizer and farm yard manure and their interaction significantly influenced physiological maturity, vine number ,vine length ,leaf number, vine internodes length, leaf area, total biomass ,total storage root yield , storage root weight, storage root diameter ,harvest index, dry matter content, TSS and moisture. However, better growth and yield of anchote was obtained when NPSB fertilizer was applied in combined with farm yard manure fertilizer as compared to alone application of blended NPSB and farmyard manure fertilizer. This is probably due to immediate availability of nutrients in chemical fertilizers and improving soil structure potential of organic fertilizer. Similarly, alone application of 10 t ha^{-1} farm yard manure fertilizer enabled to obtain highest value of growth, yield and most quality attributes of anchote. Furthermore, the interaction effect of the two fertilizers enables to recorded more value of growth, yield and quality attributes of anchote. On other the hand, application of blended NPSB fertilizer enabled to obtain better vegetative growth, yield and yield components and most quality components of anchote as compared FYM.

In conclusion, the present study showed that the combined application of NPSB blended fertilizer and FYM improved growth, yield and quality of anchote. According to this study, optimum root yield was obtained from combined application of 175 kg ha^{-1} NPSB blended fertilizer and 10 t ha^{-1} of FYM. In terms of economic point of view, the highest net benefit for root yield of anchote 23532.2 ETB ha^{-1}) was recorded from application of 175 kg NPSB ha^{-1}in combined with 10 t FYM ha^{-1} fertilizer .The lowest (12671.1ETB ha^{-1}) was observed at sole application of 291 kg ha^{-1} of NPSB fertilizer. This indicates as inorganic fertilizer is more expensive than organic fertilizer. Apart from that, similar to highest net benefit the highest marginal rate of return (MRR) (337.32%) was also obtained from application of 175kg NPSB ha^{-1} plus 10 t FYM ha^{-1}fertilizer.Therefore, these rates of fertilizer are economically feasible and recommended for Anchote production. However, sound recommendation cannot be drawn from this study since the research work was conducted only for one season in a single location and as well as growth, yield and quality of anchote can be affected by soil nutrient status, environmental condition and growing seasons.

Based on this, the following points are suggested as future line of work at the current study area.

- Evaluation on the effect of combined application of blended NPSB fertilizer and farmyard manure using this Anchote variety at different location, soil type and season.
- It is advisable to conduct similar experiments during the main rainy season at different ecologies to determine optimum Anchote productivity.
- Testing the effect of combined application of blended NPSB fertilizer and farm yard manure on quality attributes of Anchote.

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7. APPENDICES

7. APPENDICES

Appendix Table 1.Mean square values of phonological Observation and growth parameters affected by combined application of NPSB fertilizer and farm yard manure rates during the 2019 growing season at Jimma.

		Variables			
Source of Variation	DF	VN	VL	VIL	LN
Rep	2	0.0049^{ns}	0.05^{ns}	0.27^{ns}	4.98^{ns}
NPSB	5	0.57*	0.64**	4.36**	139.76**
FYM	2	6.92**	2.83**	43.87**	2159.95**
NPSB* FYM	10	0.09*	0.07*	0.52*	10.32*
Error	34	0.04	0.03	0.23	3.48

*Where; DF = degrees of freedom; EP = Emergence Percentage; DPM = Days of Physiological Maturity; VN = Vine Number; VL = Vine Length; VIL =Vine Internode Length; ns, * and ** implies non significant, significant and highly significance differences, respectively*

Appendix Table 2.Mean square values of growth and some parts of yield parameters affected by combined application of NPSB fertilizer and farm yard manure rates during 2019 growing season at Jimma.

		Variables			
Source of Variation	DF	LA	TBM	EP	DPM
Rep	2	8.11^{ns}	4.77^{ns}	1.97^{ns}	8.86^{ns}
NPSB	5	4873.35**	27.08**	84.13*	346.68**
FYM	2	114.99*	111.13**	1209.81**	1259.64**
NPSB* FYM	10	87.98*	8.62*	32.19^{ns}	25.51*
Error	34	34.99	3.93	31.56	10.73

*Where; DF = degrees of freedom; LN = Leaf Number; LA = Leaf Area; TMB = Total Biomass; NSR = Number of Storage Root; SRW = Storage Root Weight; ns, * and ** implies non significant, significant and highly significance differences, respectively.*

Appendix Table 3.Mean square values of yield parameters affected by combined application of NPSB fertilizer and farm yard manure rates during 2019 growing season at Jimma.

			Variables			
Source of Variation	DF	NSR	SRD	SRW	TRY	HI
Rep	2	0.0018^{ns}	26.25^{ns}	0.000057^{ns}	5.38^{ns}	50.63^{ns}
NPSB	5	0.014^{ns}	158.74**	0.004**	27.20**	157.93**
FYM	2	0.003^{ns}	261.95**	0.02**	246.57**	1480.09**
NPSB* FYM	10	0.006^{ns}	21.41*	0.0011**	6.49*	55.99*
Error	34	0.007	10.06	0.00013	2.73	24.39

*Where; DF = degrees of freedom; SRN=number of storage root; STD = Storage Root Diameter;; TRY = Total Root Yield; HI =Harvest Index; ns, * and ** implies non significant, significant and highly significance differences, respectively*

Appendix table 4.Mean square values of Quality parameters affected by combined application of NPSB manure rates during 2019 growing season at Jimma.

		Variables				
Source of Variation	DF	RDM	ASH	TSS	CF	MO
Rep	2	2.36^{ns}	0.10^{ns}	0.25^{ns}	0.0054^{ns}	0.02^{ns}
NPSB	5	13.98**	1.162**	0.65**	0.32**	1.49**
FYM	2	124.00**	1.93**	0.66**	2.51**	31.72**
NPSB* FYM	10	3.03*	0.17**	0.64**	0.16**	0.08**
Error	34	1.36	0.03	0.12	0.02	0.01

*Where; DF = degrees of freedom; TDM =Root Dry Matter; ASH= Ash, TSS =Total Soluble Solid; CF = Crude Fat; MO = Moisture; ns, * and ** implies non significant, significant and highly significance differences, respectively.*

Appendix Table 5.Soil and farmyard manure analyzed data at JUCAVM soil laboratory.

Samples					
Soil				Farmyard manure	
Chemical Properties		Physical properties		Chemical Properties	
Parameters	Results	Parameters	Results	Parameters	Results
pH(1:2:5)	5.5^{m}	Sand	20%	pH(1:2:5)	7.43^{ma}
OC (%)	3.65^{m}	Clay	46%	OC	31.68^{vh}
OM (%)	6.29^{m}	Silt	34%	Om	54.63^{vh}
TN (%)	0.31^{vh}			TN	2.7314^{vh}
P(PPM)	16.60^{h}			P(PPM)	2223.79^{vh}
CEC(meg/100g)	29.59^{h}			CEC	115.42v^{h}

Where,=medium=high, vh=very high,Ph=power of hydrogen,OC (%)=percent organic carbon, OM(%)=percent of organic matter,TN(%)=Total nitrogen(ppm) phosphorous parts per million and CEC(meg/100g)= cation exchange capacity.

Appendix Table 6. Post analyzed soil data for experimental site at JUCAVM soil laboratory.

FYM rate t ha^{-1}	NPSB rate kg ha^{-1}	pH	OC (%)	OM (%)	TN (%)	P (ppm)	CEC meq/100g
0	0	6.03^{sa}	2.46^{m}	4.23^{m}	0.22^{m}	15.10^{h}	24.56^{m}
58	0	6.1^{sa}	2.46^{m}	4.23^{m}	0.22^{m}	15.56^{h}	26.18^{h}
116	0	6.12^{sa}	2.46^{m}	4.23^{m}	0.22^{m}	15.6^{h}	26.56^{h}
175	0	6.14^{sa}	2.63^{m}	4.54^{m}	0.23^{m}	15.87^{h}	26.50^{h}
233	0	6.15^{sa}	2.63^{m}	4.53^{m}	0.23^{m}	16.72^{h}	26.58^{h}
291	0	6.19^{sa}	2.63^{m}	4.54^{m}	0.23^{m}	17.38^{h}	26.96^{h}
0	5	6.23^{sa}	2.63^{m}	4.55^{m}	0.23^{m}	18.5^{h}	27.18^{h}
58	5	6.45^{sa}	2.63^{m}	4.58^{m}	0.23^{m}	18.55^{h}	27.96^{h}
116	5	6.46^{sa}	2.63^{m}	4.54^{m}	0.23^{h}	19.44^{h}	27.96^{h}
175	5	6.5^{sa}	2.81^{m}	4.84^{m}	0.24^{h}	20.42^{vh}	28.56^{h}
233	5	6.53^{sa}	2.81^{m}	4.84^{m}	0.24^{h}	24.42^{vh}	29.18^{h}
291	5	6.56^{sa}	2.81^{m}	4.84^{m}	0.24^{h}	27.40^{vh}	29.18^{h}
0	10	6.67^{sa}	2.81^{m}	4.84^{m}	0.24^{h}	28.14^{vh}	29.57^{h}
58	10	6.71^{sa}	2.98^{m}	5.14^{m}	0.26^{h}	29.44^{vh}	29.78^{h}
116	10	6.76^{sa}	2.98^{m}	5.14^{m}	0.26^{h}	31.12^{vh}	30.39^{h}
175	10	6.78^{sa}	3.16^{m}	5.45^{m}	0.27^{h}	31.79^{vh}	30.39^{h}
233	10	6.88^{sa}	3.16^{m}	5.45^{m}	0.27^{h}	31.92^{vh}	30.39^{h}
291	10	6.88^{sa}	3.16^{m}	5.46^{m}	0.27^{h}	35.63^{vh}	30.76^{h}

Sa = strongly acidic, m= moderate/medium, h = high, vh = very high, pH=power of hydrogen, N=Nitrogen, P = Available phosphorus, PPM = Pascal per millennium, OC=organic carbon and OM=organic matter

Appendix Figure 7.Different pictures taken during research time, in 2019 growing season at Jimma.