



GROWTH AND YIELD OF ONION (*Allium cepa* L.) AS AFFECTED BY VARIABLE RATES OF POULTRY MANURE AND MINERAL NITROGEN FERTILIZER AT ALAGE, CENTRAL RIFT VALLEY OF ETHIOPIA

MSc THESIS

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HAWASSA UNIVERSITY, HAWASSA, ETHIOPIA

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GROWTH AND YIELD OF ONION (*Allium cepa* L.) AS AFFECTED BY VARIABLE
RATES OF POULTRY MANURE AND MINERAL NITROGEN FERTILIZER AT
ALAGE, CENTRAL RIFT VALLEY OF ETHIOPIA

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DECLARATION

This is to certify that the thesis entitled “**Growth and Yield of Onion (*Allium cepa* L.) As Affected by Variable rates of Poultry Manure and Mineral Nitrogen Fertilizer at Alage, Central Rift Valley of Ethiopia.**” Submitted in partial fulfillment of the requirements for the degree of **Master’s** with specialization in **Agronomy**, the graduate program of the department of plant and horticultural science, and has been carried out by NEJEHA REDY ALEMAR (Id. No 133/08), under our supervision. Therefore we recommend that it can be submitted as fulfillment of the thesis requirement.

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DEDICATION

I dedicate this thesis work to my beloved and respected family members, specially my brother Kedir Redy.

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 I used for writing it. I submit this thesis to Hawassa University in partial fulfillment for the Degree of Master of Science. The thesis is deposited at the library of the University to be made available to borrowers for reference under the rules and regulations of the library. I solemnly declare that the thesis has not been so far submitted to any other institution anywhere for the award of any academic degree, diploma, or certificate.

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ACRONYMS AND ABBREVIATIONS

ADP	Adenosine Diphosphate
AEZs	Agro-ecological zones
AMP	Adenosine Monophosphate
ANOVA	Analysis of Variance
ATP	Adenosine triphosphate
CEC	Cation Exchange Capacity
Cm	Centimeter
CFA	California Fertilizer Association
CSA	Central Statistical Agency
CSSE	Crop Science Society of Ethiopia
DAP	Diammonium phosphate
DNA	Deoxyribonucleic Acid
EARO	Ethiopia Agricultural Research Organization
EHDA	Ethiopia Horticulture Development Agency
FAO	Food and Agricultural Organization of the united nation
FAOSTAT	Food and Agriculture Organization Statistics.
ICAR	Indian Council of Agricultural Research

INM	Integrated nutrient management
K	Potassium
LSD	Least Significant Difference
MOARD	Ministry of Agriculture and Rural Development
N	Nitrogen
P	Phosphorus
PM	Poultry manure
RCBD	Randomized Complete Block Design
RNA	Ribonucleic Acid
SAS	Statistical Analysis System
CIMMIT	International Maize and Wheat Improvement Center

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ABSTRACT

Onion is one of the important vegetable crops produced in many home gardens and in some extent commercially in different parts of Ethiopia. However, the average yield of the crop is low compared with the world average yield. Declining soil fertility and lack of information on appropriate fertilizer type and rates are the most important factors attributing for the low yield of onion in Ethiopia. Therefore, the field experiment was carried out at Alage Central Rift Valley of Ethiopia, during 2018/19 cropping season, with the objectives of assessing the growth, yield and quality response of onion to the variable rates of poultry manure and mineral nitrogen fertilizer. The experiment comprising of three nitrogen levels (0, 46 and 92 kg ha⁻¹) and four levels of poultry manure (0, 5, 10 and 15 t ha⁻¹) were laid out in randomized complete block design with three replications. Data on plant growth, yield and quality components were collected and subjected to ANOVA using SAS (9.2 version) software. The main effects of poultry manure and nitrogen fertilizer significantly affected the leaf length, leaf number, days to maturity, bulb length, unmarketable bulb yield and bulb dry matter content, except total bulb yield and marketable bulb yield. Plant height, bulb diameter and harvest index were significantly affected by the interaction of poultry manure and nitrogen fertilizer levels. Application of poultry manure at the rate of 15 t ha⁻¹ recorded the highest total bulb yield (63.33 t ha⁻¹) and marketable bulb yield (62.52 t ha⁻¹), but statistically there were no

significant difference between 15t ha⁻¹ and 10t ha⁻¹ poultry manure application. Lower amount of total bulb yield (53.44 t ha⁻¹) and marketable bulb yield (52.40 t ha⁻¹) were obtained from the control plot as compared to the maximum yields obtained from other treatments. Marketable bulb yield was positively and significantly correlated with most of the growth parameters. The results of partial budget analysis showed that 15 t ha⁻¹ poultry manure application gave the highest marginal rate of returns. Since, the highest bulb yield and maximum marginal rate of returns are obtained at 15 t ha⁻¹ poultry manure application, this rate can be recommended for onion production in the researched area, and areas having similar agro-ecologies. However, as the research is conducted for a single season and location, repeating the experiment over location and year will be required to give a conclusive recommendation.

Key words: Bulb yield, Growth parameter, Nitrogen fertilizer and Poultry manure

1. INTRODUCTION

Onion (*Allium cepa* L.) belongs to the genus *Allium* of the family *Alliaceae* (Boukary *et al.*, 2012). It is one of the most important vegetable crops commercially grown in the world. It probably originated in Central Asia between Turkmenistan and Afghanistan where some of its relatives still grow as a wild. Onion from Central Asia, the supposed onion ancestor had probably migrated to the Near East (Grubben and Denton, 2004; Bagali *et al.*, 2012). Although the green shoots of salad onion are important, the crop is mostly grown for its bulb. Onions contribute significant nutritional value to the human diet and have medicinal properties and are primarily consumed for their unique food flavoring purpose and distinctive pungency attributed by the presence of volatile oil (*Allylpropyl disulphide*) (Ketter and Randle, 1998; Geremew *et al.*, 2010). The mature bulbs also contain some starch, appreciable quantities of sugars, some proteins, and vitamins such as vitamin A, B, and C (Decoteau, 2000; Malik, 2000).

Onions is used in several ways as in fresh, frozen, canned, pickled, powdered, chopped and dehydrated forms. Onions are primarily consumed for their unique flavor to enhance the

flavor of other foods (Randle and Ketter, 1998), in powder form as spice for seasoning in cooking (Bagali *et al.*, 2012). In addition, onion is known for its anti-bacterial, anti-viral, anti-allergenic and anti-inflammatory potential (Saha, 2013; Yemane *et al.*, 2014). It also contains some important vitamins (A, B and B2) and minerals (Ca, P, Fe, Cu and Zn) in addition to some soluble sugars and nicotinic acid (Decoteau, 2000).

Onion is grown in more than 130 countries of the world with annual production of 86.34 million metric tons (FAO, 2013). Onion ranks second after tomato among vegetable crops in area coverage (FAO, 2012). The world's top producer of onion is China, contributing about 28% to the total world production followed by India (19%). In terms of productivity, however, Ireland is the first (67.3 t/ha), followed by Republic of Korea (63.8 t/ha), USA (55.3 t/ha) and Spain (53.5 t/ha) (FAO, 2010; ICAR, 2011). In 2013, an estimated yield of 85,795,190.57 tons of onion bulb produced from 4.4 million hectares of land worldwide (FAOSTAT, 2013).

In Africa, the major producers of onion are Egypt, Algeria, Morocco and South Africa with corresponding average national yield of 25, 13.6, 18.2 and 21.1 t ha⁻¹, respectively (Bosch *et al.*, 2002).

Vegetables including onion are produced in many home gardens and to some extent, in commercial terms in different parts of Ethiopia (Fekadu and Dandena, 2006). The major producers are, however, the small-scale farmers using mainly rainfall, although some produced using irrigation (CSA, 2016). Vegetable production of the smallholder farmers in the country is mainly for self-sufficiency and to improve their income (Bezabih *et al.*, 2015). Statistics on the production of onion in Ethiopia showed that it is cultivated on about 29,517.01 ha with average annual production of 264849.35 tons. The average productivity of

onion in Ethiopia is about 8.97 t ha⁻¹ (CSA, 2016), which is very low compared to world's average of 19.30 t/ha (FAO, 2013). Different factors contribute to the low yield of onion in the country, among which lack of information on appropriate fertilizer type and level, declining soil fertility and limited water availability are the most important ones (Takele, 2004). Lack of information on appropriate nitrogen fertilizers and irrigation regimes (Pathak, 1994), soil physical and chemical characteristics, and disease and pest problems are the main factors constraining onion yield (Abbey and Joyce, 2004).

The use of appropriate agronomic practices plays a key role in increasing crop yields including onion. Optimum agronomic practices for a crop may vary with plant population, planting and harvesting dates and fertilizers used with the prevailing environmental conditions (soil fertility, rainfall, etc), purpose of production of the crop and even with cultivar within a crop. Therefore, to optimize productivity of onion crop, full information on production packages is required for a particular production area (Dessaiegn and Aklilu, 2003).

Improvement in environmental conditions with respect to public health has been observed as adoption of organic farming by farmers in the world (Eifediyi and Remison, 2010). Manure is among the organic sources of fertilizer used as an input in the organic farming system. Manures serve as safer sources of nutrition as they are environmentally friendly, release their nutrients in a slow and steady manner to crops in the field, thereby, activating soil microbial activities (Eifediyi and Remison, 2010). Organic manures sustain cropping systems through better nutrient recycling and improvement in soil physical, chemical and biological properties (Ojeniyi, 2000). On the other hand, the use of inorganic fertilizer has been observed to cause destruction of soil texture and structure which often leads to soil erosion and acidity as a result

of leaching of mineral nutrients, giving rise to reduced crop yields as a result of soil degradation and nutrient imbalance (Ojeniyi, 2000).

The use of organic manures has been recommended for long term cropping in the tropics, as slow mineralization of these manures promotes crop yield for a long period of time (Gambo *et al.*, 2008). Nevertheless the most satisfactory method of increasing crop yields is by judicious use of organic manures in combination with little portions of inorganic sources to promote nutrient use efficiency (Gambo *et al.*, 2008). It has also been observed that organic manures increase soil water holding capacity and, thus, make nutrients more readily available to crops (Dada and Fayinminnu, 2010). Poultry manure is an excellent source of organic fertilizer, which is cost effective to the farmers, and suiting with human and environmental health. It has high nutritional value for plant growth (Zang *et al.*, 1998; Ishak *et al.*, 1999).

In the study area (Alage), the use of organic fertilizer including poultry manure is not a common practice. Therefore, vegetable production is solely depends on mineral source of fertilizers which is limiting onion production and contributing to environmental pollution. Besides, the use of mineral source of fertilizer may not also be wise at small scale farmer level due to its high cost, less accessibility and reduced profit margin. However, no sufficient information is available on the combined application of poultry manure and inorganic nitrogen fertilization, which can otherwise solve the aforementioned problems. The use of poultry manure to meet the nutrient requirement of crops would be an inevitable practice in the years to come for sustainable agriculture since organic manure generally improves the soil's physical, chemical and biological properties along with improving the water holding capacity of the soil and, thus, resulting in enhanced crop productivity. Therefore, optimizing sole and

combined use of mineral and organic sources of fertilizers could be the better option to maximize crop productivity, environmental and economic sustainability. This indicates the existence of an urgent need to study the effect of combined application of poultry manure and inorganic fertilizer to optimize onion yield in the era of climate change. The main purpose of the present study was, therefore, to assess the effects of poultry manure and mineral nitrogen fertilizers application on the growth, yield and quality performance of onion.

General Objective

To study the response of onion to different application rates of poultry manure and mineral nitrogen fertilizer.

Specific objectives

To evaluate the effect of different levels of poultry manure and mineral nitrogen fertilizer on the growth performance and yield response of onion.

To study the quality response of onion to the combined application of poultry manure and inorganic nitrogen fertilizer.

To assess the economic feasibility of Poultry Manure for onion production over the use of chemical fertilizers.

2. LITERATURE REVIEW

2.1. The Onion Plant

Onions (*Allium cepa* L. var. *cepa*) originated in south-west Asia and the Mediterranean region. From these centers, onion has spread widely to many countries of the world. Onions have been used as a condiment in the cuisines of ancient China, India, and Egypt for well over 4000 years. Although its main role in cooking is to provide flavor, onion is a significant source of vitamin C and potassium, contains about 60 calories in a medium-sized bulb, and has very low sodium content. Onion and its relatives in the Alliaceae family have long been used by many cultures for the treatment of various ailments, and modern science is beginning to reveal more potential health and medicinal benefits of these plants. Of particular interest is the traditional use in many cultures of onion and garlic to improve blood circulation, which may reduce the incidence of heart attack and strokes (Valenzuela *et al.*, 1999; Rabinowitch and Currah, 2002).

Onion is one of the most important vegetable crops in Ethiopia which is used almost daily as a spice and vegetable in the local dish regardless of religion, ethnicity, and culture (CSSE, 2006). Onion has its own distinctive flavor, pungency and is eaten as fried, boiled, roasted or raw in salad as vegetable and is widely used as a condiment in preparation of soups, savory dish, canned food product, salads and sandwiches. Moreover, it is also processed as pickle, chutney, and sauces and consumed in dehydrated form (Muhammad, 2004). Onion also has great economic importance as dry onion, as process product which includes onion oils, onion juice, onion salt, onion pickles and dehydrated products and as ornamental plant thereby generating income to producers (Gambo *et al.*, 2008).

Onion is an herbaceous biennial monocot plant which cultivated as an annual crop for the purpose of bulb production; however, it is cultivated as biennial crop for seed production. During the first season bulbs are formed while flower stalks and seeds are developed in the second season (Corgan *et al.*, 2000).

Alliums are placed in the class Liliopsida, Order Amaryllidales and Family Alliaceae (Rabinowitch and Currah, 2002). Onion is a cross-fertilizing diploid species ($2n = 2 \times = 16$) in which strong inbreeding depression is present (Bassett, 1986). The majority of cultivars grown for dry bulbs and those having large bulbs and normally single bulb per plant belong to this group. In *Allium* species there are very wide variation in shape, size and color and includes hundreds of open pollinated varieties (Jones and Mann, 1963).

The onion bulb is composed of fleshy enlarged leaf base or scale (Shanmugasundaram and Kalib, 2001). As the outer leaf base loses moisture and becomes scaly and inner leaves generally thicken and develop as bulb. The sheath develops to encircle the growing points and form a tube that encloses younger leaves and the shoot apex. Collectively the grouping of these sheaths comprises the pseudo stem (Rabinowitch and Brewster, 1990). The green leaves above the bulb are hallowed and arise sequentially from the meristem at the inner most point at the base of the bulb. The pseudo stem is small and insignificant during vegetative growth (Brewster, 1994; Shanmugasundaram and Kalib, 2001). Onion root system is fibrous, spreading just beneath the soil surface to distance of 30 to 46 cm. The total root growth of onion is sparse and has few laterals. Onion roots are short lived, being continuously produced, rarely have branches and root hairs, and rarely increase in diameter (Brewster, 1994; Shanmugasundaram and Kalib, 2001).

2.2. Onion production and its importance in Ethiopia

In Ethiopia it is possible and has a great potential to produce onion throughout the year both for local consumption and export. It is grown primarily for its bulb which is used for flavoring the local stew, ‘wet’ which is considerably important in the daily diet, mostly used as seasonings or as vegetables in stews. It is one of the richest sources of flavonoid in the human diet and flavonoid consumption has been associated with a reduced risk of cancer, heart disease and diabetes. In addition it is known for anti bacterial, antiviral, anti-allergenic and anti-inflammatory potential (MoARD, 2009). Onions (*Allium cepa* L.) as bulb onion and/or shallot is probably cultivated in all countries of tropical Africa including Ethiopia (Grubben, Denton ., 2004,).

Onion requires adequate soil moisture due to the relatively short and small root system. Onions are sensitive to photoperiod. Long days are favorable to onion production as this enhances leaf development and formation which, in turn, is directly related to bulb size. Early varieties require 13 hours for bulb initiation while late varieties require 16 hours for bulb initiation. In Ethiopia onion can grow between 500 and 2400 meter above sea level, but the best growing altitude so far known is between 700 and 1800 meter above sea level (Aklilu, S. 1997,).

Lemma and Shimelis, 2003 was reported that onion grows in all types of soils on sandy loam to heavy clay. Suitable soil pH for onion ranges between 6.2 and 6.8 (Karim and Ibrahim, 2013). But on organic soils, a pH of 5.5 is considered sufficient. Temperatures around 20 – 22°C favor vegetative growth while temperatures around 12°C favor seed stalk formation (Sukprakarn *et al.*, 2005). Onion and shallot are produced in central, northern, eastern, and

northwest part of Ethiopia where there are favorable climate and soil types. The production is rapidly expanding in all administrative regions even in non-traditional bulb crop producing areas in the country in different agro-ecological zones (AEZs) either in small pockets or in large commercial farms (MARC, 2004).

The area under this crop has been expanded even if the extent of their cultivation in the peasant sector is difficult to indicate numerically because it is scattered throughout the country and small plots commonly by the side of homestead. The main production regions were Amhara, Oromia, Tigray, Benishngule-gumuz, Gambella and South Nation Nationalities and Peoples Regions, but the leading or dominantly producing regions are Oromiya (64%) and Amhara (30%), (EHDA, 2011).

The two cities Meki and Ziway are located in the fertile Lake region; this area is known as the onion belt of Ethiopia. Of the 46,600 inhabitants in Meki, 11,320 are farmers working with onion cultivation in an area of 5,650 ha. Of the 56,100 inhabitants in Ziway, 7,700 are farmers in an onion cultivation area of 11,500 ha (Citypopulation, 2013). The onion production is estimated to be 135,600 tons/year in Meki and 34,766 tons/year in Ziway (Meki & Ziway agricultural office, 2014). The onion crops have contributed to Ethiopian economy by exports of bulbs and cut flowers (Desalenge and Aklilu, 2003,).

Small farmers, private growers and some larger state enterprises in many parts of Ethiopia cultivate onions. Areas with good soil and weather conditions for the cultivation of onions are the Awash valley, Lake Region and areas close to the Sudan border (Desalenge and Aklilu, 2003,). In Ethiopia, the planted area for onions was 22,036 hectare (ha) in 2011, which corresponded to about 0.5 % of all onion-cultivated areas in the world. The production of

onions in Ethiopia in 2011 was estimated to 236,922 tons, which was about 0.27% of all world onion production (FAOSTAT, 2013).

2.3. Nutrient requirement of onion

Onion is a heavy feeder of mineral nutrients. Nitrogen (N) and phosphorus (P) are often referred to as the primary macronutrients because of the large quantities taken up by plants from the soil relative to other essential nutrients (Marschner, 1995). Onions are more susceptible than most crop plants in extracting nutrients, especially the immobile types, because of their shallow and unbranched root system (Brewster, 1990).

Nitrogen is the most principal plant nutrient required in great quantity. Nitrogen is an important component of protein, enzyme and vitamins in plants (Marschner, 1995). Nitrogen has been identified as being the most limiting nutrient in plant growth. Plants absorb nitrogen in the cation form (NH_4^+) or the anionic form (NO_3^-). Plants obtain readily available N forms from different sources. The major forms include: biological nitrogen fixation by soil microorganisms, mineralization of organic N, industrial fixation of nitrogen gas and fixation as oxides of nitrogen by atmospheric electric discharge (Tisdale *et al.*, 1995). The availability of nitrogen through biological N fixation is influenced by soil pH, and its mineral nutrient status, photosynthesis, climate and crop management (Miller and Donanue, 1995; Tisdale *et al.*, 1995).

The available nitrogen from soil can be made unavailable or lost via plant uptake, denitrification, volatilization, leaching and ammonium fixation (Tisdale *et al.*, 1995). The loss of available nitrogen through natural processes is believed to surpass the gain (Miller and Donanue, 1995; Tisdale *et al.*, 1995). To compensate for the long growing season and the

potential for nutrients to be lost by leaching due to rainfall or irrigation, apply N several times during the growth period. About 75 percent of the N uptake takes place after bulbing begins. Deficient amounts of available N result in early bulb maturity and reduced bulb size. High N levels, although increase bulb size, may (if excessive) cause large necks, double center, increased pungency, and soft bulbs with poor storage quality (Valenzuela *et al.*, 1999).

Phosphorus availability is especially important during the first half of the onion crop growth cycle, and Phosphorus is usually applied before planting if the need is indicated by soil analysis. To amend the phosphorus status of the soil, phosphorus fertilizer must be thoroughly mixed with the soil in the onion root zone before planting (Valenzuela *et al.*, 1999). Phosphorus is making up about 0.2% of a plant's dry weight and it is essential for root development. It is also a vital component of nucleic acids (DNA and RNA), energy molecules (AMP, ADP and ATP) and phospholipids. Inadequate availability of these nutrients in the soil affects the growth and development of crop plants including onion. In such cases therefore, soils should be supplemented with plant nutrients in the form of fertilizers. In onions, P deficiencies reduce root and leaf growth, bulb size and yield and can also delay maturation, Generally onions are more susceptible to nutrient deficiencies than most crop plants because of their shallow and unbranched root system. Hence they require and often respond well to the addition of both inorganic and organic fertilizers (Brewester, 1994).

2.4. Poultry manure

The poultry industry is one of the largest and fastest growing agro-based industries in the world. There is an increasing demand for poultry meat mainly due to its acceptance by most societies and its relatively low cholesterol content. The poultry industry is currently facing a number of environmental problems. One of the major problems is the accumulation of large

amount of wastes, especially manure and litter, generated by intensive production, Large-scale accumulation of these wastes may pose disposal and pollution problems unless environmentally and economically sustainable management technologies are evolved (Power and Dick, 2000; Kelleher *et al.*, 2002; Sharpley *et al.*, 2007). Most of the manure and litter produced by the poultry industry is currently applied to agricultural land. When managed correctly, land application is a viable way to recycle the nutrients such as nitrogen (N), phosphorus (P) and potassium (K) in manure (Sharpley *et al.*, 1998; Casey *et al.*, 2006; Kaiser *et al.*, 2009). Addition of poultry manure to soils not only helps to overcome the disposal problems but also enhances the physical, chemical and biological fertility of soils (Friend *et al.*, 2006; McGrath *et al.*, 2009).

Poultry manure is a potential source of plant nutrients and chemical conditioner. The exchangeable bases increased with application rate in all soil types, thus indicating positive effects on soils. Similarly, significant increases of N and P were observed following addition of poultry manure (Dikinya and Mufwanzala, 2010).

Poultry manure improved soil nutrient status by increasing soil organic carbon, total N, available P and exchangeable K, Ca and Mg. Ewulo *et al.* (2008) reported an increase in soil nutrient contents due to the application of poultry manure. They said that improved soil nutrient contents caused by the addition of poultry manure led to increased uptake of N, P, K, Ca and Mg by tomato plant (Adekiya and Agbede 2009). Adesodun *et al.* (2005) also found that the application of poultry manure to soil increased soil organic matter, N and P and aggregate stability. The improvement in soil physical properties was attributed to improvement in soil organic matter content. Aluko and Oyedele (2005) reported that poultry

manure improved soil moisture and was attributed to the mulching effect of organic matter and improved moisture retention as a result of improved soil structure and macro porosity.

Soil organic matter has a benefit in increasing the response to mineral fertilizers, thereby increasing the efficiency of fertilizer use. In addition, a major reason for the low efficiency of fertilizers in sub Saharan Africa is the declining level of SOM. Improving the efficiency of mineral fertilizers with SOM could expand the number of fertilizer users. Furthermore, using organic soil ameliorants in conjunction with slow-release minerals has the advantage of increasing the nutrient storage capacity of the soil (Kumwenda *et al.*, 1995).

Biological activities in the soil increase by increasing soil organic matter, which increases biological weathering, which in turn is important for releasing nutrients from minerals added to the soil. Some organic fertilizers, such as poultry litter or blood meal, behave more like mineral fertilizers because they are low in carbon and contain a lot of readily available nitrogen. Their impact therefore is more important for immediate soil nutrient status than for improving overall soil quality and SOM status. Thus depending on the soil type, the quantity and quality of SOM, and the fertility status, organic amendments can have significant effect. The quality of organic residues and SOM are as important as their quantity. Improving the quality of organic matter, that is increasing its biologically active fraction, can lead to increased aggregation in soils even when no change in the quantity of SOM can be detected (Kumwenda *et al.*, 1995). Organic matter such as sheep and chicken manure, improves soil physical and chemical properties that are important for plant growth. Application of organic fertilizer increased the biomass yield of the main crop (Synman *et al.* 1998).

In an experiment conducted to evaluate the effect of plant nutrient source and weeding regime on the growth and yield of onion, poultry manure significantly produced the highest number of leaves per plant among the different sources of plant nutrients. It was also observed that poultry manure produced larger bulb size and the highest bulb yield than other fertilizer sources (Tukur *et al.*, 2009). The superiority of poultry manure over the other plant nutrient sources with respect to number of leaves per plant, bulb size and bulb yield was attributed to the high nutrient content and its ability to release adequate nutrients to the plants, leading to the development of adequate leaf area index, which is necessary for assimilate production and translocation to sinks (Adu Boakye, 2011).

Dauda *et al.* (2008) studied the efficacy of different levels of poultry manure on the growth and yield of watermelon (*Citrullus lanatus*). The results showed that application of poultry manure significantly enhanced growth and yield. They attributed the significant performance of watermelon over the control in growth parameters and yield to the fact that poultry manure contained essential nutrient elements associated with high photosynthetic activities and thus promotes vegetative growth. Increased number of fruits and average weight was attributed to the ability of poultry manure to promote vigorous growth, increase meristematic and physiological activities in the plants due to supply of plant nutrient and improvement in the soil properties, thereby, resulting in the synthesis of more photo-assimilates, which is used in producing fruits. Hence, an increase in fruit number and size. Aliyu (2003) reported that poultry manure supplies nutrients, which enhance vigorous growth and increase yield.

In an experiment involving the use of poultry litter for vegetable production, the level of poultry litter application affected carrot yield significantly. Application of poultry litter gave

better yields of carrot than application of cattle manure and the control. Poultry litter is better than cattle manure for cabbage. Lack of positive response to increasing levels of poultry litter was attributed to the low C/N ratio which might have resulted in the loss of nitrogen through volatilization and leaching (AMAS, 2001).

2.5. Response of onion to organic fertilizer

Organic sources of plant nutrients are considered as an important factor for onion production (Funda *et al.*, 2011). Organic material such as sheep and chicken manures improve the physical, chemical, and biological properties of soils that are important for plant growth (Synman *et al.* 1998).

Organic matter in the soil directly contributes to the plant nutrients, influences CEC and binds heavy metals and pesticides. Organic matter content of the soil is the key property that determines the availability status of essential nutrients (Katyal, 2000).

The research results from Shaheen *et al.* (2007) showed that the application of a mixture of chicken manure and bio fertilizer increased the yield of onion. Onion yield was also significantly increased by the application of organic manure as indicated by Ezekiel *et al.* (2014). Similarly, there was a significant linear effect on total onion yield with increasing fresh poultry litter applications from 0 to 22 t/ha (Boyhan *et al.*, 2010).

According to Mia *et al.* (2007) the application of 10 t ha⁻¹ of poultry manure was found to be useful to reduce 50% inorganic N in onion cultivation. For yield maximization, poultry manure at 10 t ha⁻¹ along with 50% recommended dose of inorganic N appeared to be the best in respect of fertility management by enriching the soil with organic matter and turning vegetable cultivation towards organic farming. Replacing the chemical fertilizers by poultry

manure will considerably benefit the farmers and it will definitely reduce the environmental pollution caused by chemical fertilizers.

Improvement in environmental conditions with respect to public health has been observed as some of the major reasons for the need to adopt organic farming by farmers in the world (Eifediyi and Remison, 2010). Though manures are usually very bulky and the cost of transporting them from one location to another is high, but is a safer source of nutrition as they are environmentally friendly, releases their nutrients in a slow and steady manner to crops in the field thereby activating soil microbial activities (Eifediyi and Remison, 2010).

Organic manures also, sustain cropping systems through better nutrient recycling and improvement in soil physical, chemical and biological properties (Ojeniyi, 2000). The use of inorganic manures has been observed to cause the destruction of soil texture and structure which often leads to soil erosion, acidity as a result of leaching effects of mineral nutrients (Ojeniyi, 2000). However, onion yield response to animal manure or compost rates was not always positive (Abdelrazzag, 2002; Gambo *et al.*, 2008). The nitrogen availability from manure varies greatly depending on the type of animal, type and amount of bedding, and age and storage conditions of the manure (Bary *et al.*, 2000).

Adekiya and Agbede (2009) found that application of poultry manure resulted in better growth and yield of tomato than NPK fertilizer alone. It improved the performance of tomato and its nutrient status. The finding that all levels of poultry manure performed better than the NPK fertilizer alone was attributed to the fact that poultry manure supplied more nutrients than NPK fertilizer. The poultry manure could have supplied micronutrients which are essential for tomato growth and yield.

Figueiredo *et al.* (2009) reported that Corn productivity in tropical low-external input systems is usually limited by low soil fertility because crop uptake leads to a gradual depletion in soil nutrient stocks. Since the use of chemical fertilizers is undesirable, management of the fertility of these soils depends primarily on low-cost processes based on nutrient recycling. They also reported the main processes that contribute to this recycling are biological nitrogen fixation (BNF) and nutrient recycling via organic fertilization.

The major factor contributing to declining crop yields is reduced soil fertility caused by continuous cropping without the addition of sufficient mineral fertilizers and manure (Ndayisaba, 2014). The need to reduce costs of fertilizing crops with renewable forms of energy has revitalized the application of organic fertilizers worldwide. The main reason for promoting the increased use of organic materials is to improve environmental conditions and public health (Ojeniyi, 2000; Maritus and Vlelc, 2001).

The harmful effects on the environment due to the heavy use of N fertilizers are becoming more evident. There is a need for sustainable farming in which soil fertility is maintained by the use of inexpensive renewable resources that are readily available on the farm. The supply of other nutrients such as P can also be increased with the use of bio-fertilizers (BFs) (Mayer *et al.*, 2008; Oliveira *et al.*, 2009).

Organic fertilizers, including farmyard manure, chicken manure (CM), sheep manure, and BFs, may be used for crop production as a substitute for chemical fertilizers (Khan *et al.*, 2005). Compared with chemical fertilizers, organic fertilizers improve soil fertility without leaving any residual effects in the soil and are much more inexpensive (Chater & Gasser, 1970).

Nutrients are released more slowly from organic manure and stored for longer time periods in the soil, thus ensuring a long residual effect (Sharma & Mitra, 1991; Abou *et al.*, 2005). Chicken manure was found to be a viable substitute for chemical fertilizers (Khan *et al.*, 2005) and strongly positively affected both the moisture-holding capacity and structure of the soil (Sharif *et al.*, 2004).

Generally appropriate type and rate of application of organic fertilizers can help to reduce the use of inorganic fertilizers and sustain production and productivity of crops including onion and to minimize environmental pollution.

2.6. Response of onion to inorganic fertilizer

Optimum amounts of plant nutrients Application play a significant role in increasing production, productivity and quality of vegetable crops including onion. Onion is more responsive to the application of inorganic fertilizer especially that of nitrogen fertilizer as it is a shallow rooted vegetable (Drost and Koenig, 2001). On the other hand application of excess nitrogen can encourage foliar growth and depresses onion bulb growth (Brewster, 1990). The application of fertilizer however depends on the fertility status of the soil, the environmental conditions and the developmental stages of the crop. Generally application of nitrogen at the early growth stages of onion promote bulb formation by involving in the formation of dormant structure and in increase insoluble carbohydrate, while lower levels delay the bulbing process (Drost and Koenig, 2001).

Nitrogen is required for plant growth in much greater quantities than most other nutrients. It is an important component of chlorophyll molecules, proteins, enzymes and vitamins in plants. It also helps to enhance carbohydrate utilization, to improve development and activity of roots as

well as to support uptake of other nutrients (CFA, 1995). Increased application of nitrogen gives faster rate of leaf expansion, increased leaf area index, leaf area duration, photosynthetic rate and increased radiation interception and radiation use efficiency (Connor *et al.*, 1993). More Nitrogen is required for vegetative growth than for reproductive development (Smith and Hamel, 1999). Adequate supply of nitrogen promotes higher photosynthetic activity and vigorous vegetative growth, and as a result the plants turn into dark green color (Balasubramanian and Planiappan, 2001).

Onion is a heavy feeder, requiring ample supplies of nitrogen, phosphorous, and potassium. Sub optimal levels of nitrogen, phosphorous, and potassium nutrients in the soil adversely affect the yield and quality of bulbs (Gubb and Tavis, 2002). Too much N can result in excessive vegetative growth, delayed maturity, increased susceptibility to diseases, reduced dry matter contents and storability and thus, result in reduced yield and quality of marketable bulbs (Sørensen and Grevsen, 2001; Kebede, 2003). When nitrogen is limited, crop growth is slow and yields are reduced. Under sub-optimum supply of nitrogen, onions can be severally stunted with bulb size and marketable yields reduction (Kebede, 2003). Gustfson, (2010) also reported that Nitrogen in plant controls the utilization of P and K and excess could delay maturity by causing too much vegetative growth.

Nitrogen fertilization is greater importance for onion production (Rabinowitch and Currah, 2002). According to Kebede (2003) and Lemma and Shimeles (2003), onion is responsive to nitrogen fertilizer. Brewster and Butler (1989) and Halvorson *et al.* (2002) reported that the lower the nitrogen, the later bulb scale initiation occurred and also indicated that an initial period of low N delayed bulb scale development and ripening relative to high N throughout.

Effect of nitrogen on vegetative growth, yield attributes and yield of onion is documented by Ghaffoor *et al.* (2003), Jilani *et al.* (2004), Aliyu *et al.* (2007), Nasreen *et al.* (2007), and Gustfson (2010). Nasreen *et al.* (2007) reported that nitrogen had a significant effect on the vegetative growth and yield attributes of onion. According to this experiment application of 120 kg N ha⁻¹ increased the number of leaves per plant and plant height significantly over the control as well as lower levels of N. It also indicated that the size and weight of bulbs were increased due to application of nitrogen up to 120 kg ha⁻¹, which decreased thereafter.

An investigation was carried out at Melkassa Agricultural Research Center and Upper Awash Agro-Industry Enterprise, Ethiopia from 1988 to 1992, using equal level of N and P₂O₅ (0, 46,92 and 138 kg ha⁻¹) under heavy clay and sandy soils. The highest dry bulb yield 28.9t ha⁻¹ and 32t ha⁻¹ was produced at 92 kg ha⁻¹ at Melkassa and Nura Era, which were also 10 % and 18 % higher than the control, respectively. At 92 kg ha⁻¹, there was better vegetative growth and the average bulb weight increased to 49 and 60 g/bulb at Melkassa and Nura Era, respectively (Lemma and Shimeles, 2003). Furthermore, the authors noted that application of 92 kg N ha⁻¹ gave high dry bulb yield, which was 11% and 19% higher than the check.

Research conducted by Nasreen *et al.* (2007) and Al-Fraihat (2009), indicate that increasing nitrogen application rates up to certain ranges significantly enhanced plant height, number of green leaves/plant and weight of plants and bulbs at different growth stages of onion. Moreover total and percentage of marketable yields were doubled with increased nitrogen fertilizers. Furthermore, bolter plants as well as total soluble solids were also increased. Similarly In the research findings of Lee-Jongatae *et al.* (2003), the application of nitrogen at

the rate of 180 and 240 kg/ha, respectively, gave the highest plant height and bulb diameter. However, the highest marketable yield of onion was obtained at rate of 120 kg/ha of nitrogen.

Abdissa Yadeta *et al.* (2011) also found that about 8% increases in number of leaves over the control was observed by the application of 92 kg/ha nitrogen. On the other hand, leaf diameter and bulb length were not influenced by nitrogen fertilizer rates. Regardless of the rate of application, nitrogen increased bulb diameter and bulb weight by about 12 and 21.5%, respectively, over the control, while phosphorus did not showed significant effects on all of the onion growth parameters studied. Brewster (1990) also reported an increase in onion bulb weight to leaf blade ratio with a decrease in soil nitrogen levels. Therefore application of optimum amount of inorganic fertilizer is necessary to improve growth, yield and yield components of onion.

Generally, they found that addition of nitrogen fertilizer exerted significant influence on the number of leaves per plant, plant height, and diameter of bulb, bulb weight, and yield of onion. Similarly, Aliyu *et al.* (2007) reported that bulb yield of onion was significantly affected by application of nitrogen; i.e. increase in nitrogen rate up to 100 kg ha⁻¹ resulted in 59.2 % increase in yield of onion bulb, but further increase did not have significant effect. Kumar *et al.* (1998) also reported that the highest plant height, leaf length, number of leaves per plant, bulb diameter, bulb length, bulb fresh weight, bulb dry weight, time to bulb maturity and bulb yield were obtained from 150 kg ha⁻¹ when urea was applied in split doses.

2.7. Combine application of organic and inorganic fertilizers

Integrated nutrient management is the method of integrating organic and inorganic fertilizers to provide excellent opportunities to overcome all the imbalances besides sustaining soil

health and enhancing crop production (Yadav *et al.*, 2015). It optimizes the benefits of using all possible plant nutrients for the production of crops in an integrated manner. In this regard reports indicated that the application of Poultry manure combined with mineral fertilizer can exhibit long residual effect, which improves growth and yield (Palm *et al.*, 1997).

The use of organic manure is more beneficial when combined with inorganic fertilizers (Mugwira and Murwira, 1998). Dalzell *et al.* (1987) reported that combined application of compost and inorganic fertilizers have resulted in better juice quality in sugar cane and in higher dry matter yields per plant in tomatoes.

Poultry manure alone or in combination with mineral fertilizer exert more beneficial effects on fruit yield when compared to mineral fertilizer applied alone (Blandari *et al.*, 1989). Poultry manure alone and its combination with NPK fertilizer in first year of application and their residual effects improved degree of saturation, soil moisture content and lower soil bulk density in both forest and savannah zones, it was significantly better in the forest soils. Better water stable aggregate, porosity, void ratio and air filled porosity due to residual effects of poultry manure and fertilizer combination were also reported. This was contrary to fertilizer applied alone which reduced some of the above properties (Isitekhale and Osemwota, 2010).

Awodun (2007) carried out a study to find out the effect of poultry manure and NPK fertilizer on the growth, leaf nutrient content and yield components of *Telfaria* (*Telfaria occidentalis* Hook F) at two sites in Akure, Nigeria. The treatments applied were 0, 2, 4, 6 t ha⁻¹ poultry manure and 250 kg ha⁻¹ NPK 15-15-15 fertilizer. Application of 250 kg ha⁻¹ of NPK fertilizer gave the highest number of leaves and stem girth at the two sites. He attributed this to high and fast release of nutrients in the NPK as against the use of the poultry manure.

Gonzalez *et al.* (2001) reported that chemical fertilizer and organic manure, which were supplied as essential nutrition at the initial establishment stage, produced the best results for the measured parameters, such as plant height. Increased plant height in response to applications of combined fertilizer is attributed to more availability of N from both urea and manure throughout the growing season. Compared with control treatments, 50% poultry manure+50% chemical treatments resulted in the tallest corn plants in corn-legume cropping systems (Saleem, 2010).

Vanlauwe *et al.* (2002) reported that the integrated use of inorganic and organic nutrient sources resulted in synergy and improved the conservation and synchronization of nutrient release and crop demand, which led to increased fertilizer efficiency and greater yields. Dudal and Roy (1995) indicated that the use of organic fertilizer could increase the efficiency of inorganic fertilizer.

Chemical fertilizers are always available to provide an immediate supply of nutrients to plants if the situation demands. In contrast to inorganic fertilizers, one aspect of organic fertilizers is their slow-release capability. Slow release means there is less risk of over-fertilization, but sometimes the slow release of organic fertilizers is not able to fulfill the supply of the nutrients needed when required (Baghdadi *et al.*, 2018).

A chemical fertilizer is defined as any inorganic material of wholly or partially synthetic origin that is added to the soil to sustain plant growth. Many artificial fertilizers contain acids such as sulfuric acid and hydrochloric acid; these acids tend to increase the acidity of the soil, reducing the soil's population of beneficial organisms and interfering with plant growth. In contrast, organic fertilizers support the growth of N-fixing bacteria. Healthy soils contain

enough N-fixing bacteria to fix sufficient atmospheric N to supply the needs of growing plants. However, the continued use of chemical fertilizers may diminish the amount of these N-fixing bacteria (Baghdadi *et al*, 2018).

Combinations of CM and NPK fertilizers could be considered a better option for increasing fertilizer use efficiency and providing a more balanced supply of nutrients (Suge *et al*, 2011). Complementary use of chemical fertilizer and organic manures has assumed great importance nowadays to maintain as well as sustain a higher level of soil fertility and crop productivity (Shalini *et al*, 2002).

3. MATERIALS AND METHODS

3.1. Description of the Study Area

The study was conducted in the experimental field of Alage Agricultural Technical and Vocational Education and Training College. The site is located 217 km away from the capital city, Addis Ababa, in the southern direction and 32 km west of Bulbula town in the vicinity of Abidjata and Shalla lakes. It is situated at 7° 65' N latitude and 38° 56' E longitudes and at an altitude of 1600 meters above sea level in the dry plateau agro ecology of the southern part of the central rift valley of Ethiopian. The area is characterized by a bimodal rainfall pattern where short rainy season occurs during the months of March and April and the main rain starts in June and extends to September. The area receives relatively high amount of rainfall is in the months of July and August. The mean total annual rainfall is 800mm, with annual mean minimum and maximum temperatures of 11 °C and 29 °C, respectively. The soil textural class of the area ranges from sandy loam to sandy clay loam with some clay loam and few clay soils (Eylachew, 2004). Its reaction is slightly alkaline (pH = 7.87), which is suitable for onion production (Lemma and Shimeles, 2003). The soil is medium in total nitrogen (0.14%) and organic carbon (1.61%) (Tekalign *et al.*, 1994), and low in phosphorus (3.38 mg/kg) and EC (1.24 ds/m) (Landon, 1991).

3.2. Description of the Experimental Materials

Onion variety Bombay red was used for the study, as it is dominantly produced in the experimental area:

Table 1. Detail description of the onion variety (Bombay red) used for this experiment

Characteristics	
Leaf color	Dark green
Leaf arrangement	Medium
Bulb size (g)	85-100
Bulb shape	Flat globe
Bulb skin color	Light red
Bulb flesh color	Reddish white
Maturity (days)	100- 120
Altitude (m)	700-2000
Farmers yield (t ha ⁻¹)	13-16
Dry bulb (t ha ⁻¹)	30
TSS%	9-11
Growing altitude (m.a.s.l)	500-2400
Optimum altitude (m.a.s.l)	700-1800
Soil pH level	6.5-7
Seeding rate (kg/ha)	3-4

Source: (EARO, 2004)

3.3. Experimental Treatments and Design

The experiment consisted of factorial combinations three levels of mineral nitrogen fertilizer (0, 46, and 92 kg ha⁻¹) and four levels of poultry manure (0, 5, 10 and 15 t ha⁻¹) which were laid out in randomized complete block design (RCBD) with three replicates. Each treatment combination was assigned randomly to the experimental units within a block. The onion plants were planted on the plots using double rows on ridges with spacing of 40cm between ridges

20cm between the double rows and 10cm between plants (40cm x 20cm x 10cm). Each experimental plot had 2 m length and 2 m width having an area of 4 m², with six double rows, and 20 plants per row and, thus, total plants were 200 per plot. The distance between plots and blocks were 0.5 m and 1 m, respectively. Details of the treatment combinations are given in Table 2.

Table 2. Treatment combination of mineral nitrogen and poultry manure with their respective codes

Treatment number (code)	Poultry manure (t ha ⁻¹)	Nitrogen fertilizer (kg ha ⁻¹)	Treatment combination
1	0	0	0 t ha ⁻¹ PM+0 kg ha ⁻¹ N
2	5	0	5 t ha ⁻¹ PM+0 kg ha ⁻¹ N
3	10	0	10 t ha ⁻¹ PM+0 kg ha ⁻¹ N
4	15	0	15 t ha ⁻¹ PM+0 kg ha ⁻¹ N
5	0	46	0 t ha ⁻¹ PM+46 kg ha ⁻¹ N
6	5	46	5 t ha ⁻¹ PM+46 kg ha ⁻¹ N
7	10	46	10 t ha ⁻¹ PM+46 kg ha ⁻¹ N
8	15	46	15 t ha ⁻¹ PM+46 kg ha ⁻¹ N
9	0	92	0 t ha ⁻¹ PM+92 kg ha ⁻¹ N
10	5	92	5 t ha ⁻¹ PM+92 kg ha ⁻¹ N
11	10	92	10 t ha ⁻¹ PM+92 kg ha ⁻¹ N
12	15	92	15 t ha ⁻¹ PM+92 kg ha ⁻¹ N

3.4. Agronomic Practices and Treatment Applications

Seedlings were raised in nursery beds having a width of 1.0 m and 5.0 m length. The nursery site was well cleared, ploughed thoroughly and made into a fine tilth. Onion seeds were drilled into rows of 10 cm apart, and the seed beds were mulched with grass until germination. As soon as the seeds start germination, the mulching material was removed. Seedbeds were regularly irrigated manually twice per day with the help of watering can. Other management practices, such as weeding, cultivation and disease and insect pest control, were performed as required. Seedlings were hardened before transplanting to the main field to enable them

withstands the field conditions. After 45 days of sowing at 3 to 4 true leaf stage with 12-15cm height, healthy and vigorous seedlings were selected and transplanted to well-prepared experimental plots.

The experimental field was ploughed by using tractor and harrowed by harrower, leveling and ridging was made manually right before planting. Seedlings were carefully transplanted to the experimental plots using double rows; with 40 cm between double rows and 20 cm between the rows within the double rows and 10 cm between plants (40cm x 20cm x 10cm). Each experimental plot had 2 m length and 2 m width having an area of 4 m², with six double rows, 20 plants per row and a total of 200 plants per plot.

The full amount (dose) of poultry manure of each treatment (i.e. 0, 5, 10 and 15 t ha⁻¹) was applied during land preparation, 15 days before transplanting. The recommended rates of (P₂O₅) for onion for the study area (92 kg/ha) was applied in the form of TSP uniformly to all plots during transplanting, when half dose of Nitrogen (N) rate of each treatment was also applied as two sides dressing. The remaining half dose of N was side-dressed 45 days after transplanting. The source of N was urea fertilizer (46% N). Other than the treatments, field management practices including disease, pest and weed control and cultivation were uniformly applied to all plots as per the recommendation made for the crop (EARO, 2004).

3.5. Soil sampling and analysis

Soil samples were randomly collected before sowing from the field using diagonal method of sampling at a soil depth of 0-20cm for determination of physical and chemical properties of the soil. At least nine sampling unit per plot was taken using auger and composite the samples. The soil was air dried and broken in to small crumbs and thoroughly mixed. From this

mixture, a sample weighing about one kg was filled in to a plastic bag, and the prepared sample was sent to horticoop Ethiopia soil and water analysis laboratory for the laboratory analysis.

The soil texture was determined by the Hydrometer method. Soil pH was measured in a 1:2.5 soil-water ratio using a glass electrode pH meter. The soil-water solution stirred thoroughly and allowed to stand for 30 minutes. After calibrating the pH meter with buffers of pH 4.01 and 7.00, the pH read by immersing the electrode into the upper part of the soil solution and the pH value was recorded.

The soil samples were analyzed for total nitrogen, available phosphorous, and cation exchange capacity (CEC) and organic carbon. Total nitrogen in the soil was determined by the Kjeldahl method (Horneck *et al.*, 2011). Organic carbon content of the soil was determined by wet combustion procedure as out lined by Walkley and Black (1934). Cation exchange capacity (CEC) was determined by ammonium acetate method (Cottenie, 1980). Available phosphorous content of the soil was determined by extraction with 0.5M NaHCO₃ (Olsen *et al.*, 1954). Phosphorus in the extracts was determined with atomic absorption spectrophotometer calorimetrically according to the procedure described by Olsen and Sommers (1982).

3.6. Poultry manure sampling and characterization

The standard method of sampling with the advent of nutrient management planning is sampling litter while still in the poultry house. Sample representing the entire litter volume was collected with point method of sampling and prepared for physical and chemical analysis. A sub sample was composited and put in to a plastic bag, labeled and sent to Oromiya soil and water design agency for laboratory analysis.

3.7. Field data collection

Data on onion growth parameters and bulb characters were recorded at physiological maturity stage and harvesting, respectively, and expressed as average of ten randomly taken plants in each experimental plot. Maturity and yield data were collected on net plot basis. Accordingly, the following data were collected on the following parameters.

3.7.1. Growth and Phenological parameters

Plant height (cm): Plant height was recorded in centimeters at physiological maturity stage by measuring the height of each plant from soil surface to the tip of the longest mature leaf using ruler.

Number of Leaves per plant: It refers to the mean number of leaves produced by sampled plants at maturity. Total number of leaves of sampled plants were counted and divided by the number of plants to get mean leaf number per plant.

Leaf length (cm): it was recorded that of the average lengths in centimeter of the longest leaf from ten plants at maturity stage were measured by a ruler.

Days to maturity: The days to maturity were recorded starting from date of transplanting to the date when 70% of plants shows neck fall (EARO, 2004).

3.7.2. Yield and yield component parameter

Bulb length (cm): Bulb length should be expressed in centimeter and measured using caliper and then, average bulb length were calculated.

Bulb diameter (cm): The diameter of ten randomly selected plants bulbs were measured at the widest point in the middle portion of the mature bulb using a slide caliper.

Average bulb weight (g): refers to the bulb weight of randomly selected plants weighted using a digital balance.

Total biomass yield (t ha⁻¹): all above ground and underground biomass from net plot weighed after harvest using balance.

Unmarketable bulb yield (t ha⁻¹): refers to small sized (<3cm in diameter), discolored, physiological disordered and pest damaged bulbs which was determined from weight of bulbs harvested from the net plot using digital balance (Moray *et al.*, 2012).

Marketable bulb yield (t ha⁻¹): refers to yield of onions, which are (>3cm in Diameter), free from physiological disordered and pest damaged bulbs. It was determined from weight of bulbs harvested from the net plot using digital balance.

Total bulb yield (t ha⁻¹): was recorded from net plot by weighed all bulbs taken from central row (5) and converted in to t ha⁻¹.

Bulb dry matter content: was determined after a homogenate was prepared from bulbs of each plot after harvest. So, 100 g of the chopped homogenous bulbs were taken and oven dried at a temperature of 70°C to a constant weight. Then the weight was measured using digital balance. Finally, percent dry matter was calculated by dividing the oven dried bulb samples by their respective fresh weights.

Harvest index: was determined as the ratio of the dry bulb weight to dry biological yield of the onion.

3.8. Methods of data analysis

All the relevant data collected from the experimental plots were subjected to analysis of variances (ANOVA), which was computed using SAS computer soft ware program (Version

9.2). Significant treatment means were compared using least significant difference (LSD) test at $P < 0.05$ probability level.

3.9. Partial budget analysis

Partial budget analysis was conducted using the methodology described by CIMMYT (1988). It was used to organize experimental data and information about the cost and benefits of various alternative treatments. Bulb yield ha^{-1} , gross benefit (GB), total variable cost (TVC) and net benefit (NB) are concepts used in the partial budget analysis. The following formula was used to estimate the cost and benefits of different treatment combinations: The (gross field benefit) GFB ha^{-1} was obtained as a product of real price of onion yields for each treatment.

Gross benefit = Adjusted yield x unit price

Adjusted yield (t ha^{-1}): is the average yield adjusted downward by 10% to reflect the difference between the experimental yield and yield of farmers. Because of optimum and management, better crop is expected under experimental condition.

Adjusted Yield = Average Yield - (Average Yield*0.10)

The total variable cost in the partial budget analysis refers to the sum of cost of all variable inputs and managements practices. Whereas, Net benefit (NB ha^{-1}) was calculated by subtracting the total cost of production from the gross benefit. Any treatment that has net benefits less than or equal to those of a treatment with lower costs were considered as dominated and excluded in the analysis of marginal rate of return (MRR). For the majority of situations, the minimum rate of return acceptable to farmers is between 50 and 100% (CIMMYT, 1988). Therefore, the minimum acceptable marginal rate of return was considered to be 100 % in this study. The following formula was used to calculate MRR:

$$\text{Marginal rate of return (\%)} = \frac{\text{change in net benefit}}{\text{change in total cost}} \times 100$$

4. RESULT AND DISCUSSION

4.1. Selected soil physico-chemical properties of the experimental area

Results of laboratory analysis of the soil before planting showed that it was silty clay in texture, having particle size distribution of 17% sand, 43% clay and 40% silt. Its reaction was slightly alkaline (pH value of 7.11), which is believed to be suitable for onion production (Lemma and Shimeles, 2003). The soil was medium in total nitrogen (0.14%), available phosphorus (22.66 ppm) and organic carbon (1.63%) Tekalign *et al.* (1994). The CEC content of the experimental soil before was 38.72 cmol (+) kg⁻¹, with organic matter content of 2.81% and EC of 1.94 ds/m. Details of the laboratory results of some physiochemical properties of the soil samples taken before planting and that of poultry manure (PM) are presented in Appendix Table 5 and Appendix Table 6, respectively.

After harvesting, the soil analysis was done for the plots which were received the respective treatment combinations, where the soil samples from the three blocks were composited for each treatment. Accordingly, the pH level of the soil gradually increased with increasing rate of N fertilizer and poultry manure (PM) (Table 3). The result showed that total nitrogen content was in the ranges of medium to high (0.12%-0.25%), while electrical conductivity value of the soil ranged from 1.26 to 1.50 ds/m, which was in low range (Landon, 1991). On the other hand, CEC of the soil after harvesting was high which indicates the high cations holding capacity of clay soils (Horneck *et al.*, 2011). In general, results of the soil analysis after harvesting showed increasing trend with increased rates of N and PM application for Av.P and OM content, though values similar to those measured before planting were observed in some cases (Table 3).

Table 3. Effects of poultry manure (PM) and nitrogen (N) fertilizer on some soil properties of after harvesting at Alage, Ethiopia, during 2018 growing season.

No.	Chemical properties of sampled plots soil						
Treatment combination	pH	EC (ds/m)	CEC (cmol(+)/kg)	TN%	Avai.P(ppm)	OM%	
1. 0t ha ⁻¹ PM +0kg N ha ⁻¹	7.10	1.26	38.20	0.12	20.31	2.4	
2. 5t ha ⁻¹ PM+0 kg N ha ⁻¹	7.14	1.28	38.41	0.18	25.50	3.6	
3. 10t ha ⁻¹ PM+0 kg N ha ⁻¹	7.17	1.31	38.50	0.22	28.82	4.4	
4. 15 t ha ⁻¹ PM+0 kg N ha ⁻¹	7.21	1.35	39.56	0.22	29.46	4.4	
5. 0 t ha ⁻¹ PM+46 kg N ha ⁻¹	7.15	1.30	38.30	0.17	22.32	3.4	
6. 5 t ha ⁻¹ PM+46 kg N ha ⁻¹	7.18	1.37	38.70	0.25	27.25	5.0	
7. 10 t ha ⁻¹ PM+46kg N ha ⁻¹	7.21	1.40	39.49	0.31	29.50	6.2	
8. 15 t ha ⁻¹ PM+46 kg Nha ⁻¹	7.24	1.50	41.41	0.35	33.00	7.0	
9. 0 t ha ⁻¹ PM+92 kg N ha ⁻¹	7.14	1.33	38.50	0.19	26.11	3.8	
10. 5 t ha ⁻¹ PM+92 kg N ha ⁻¹	7.21	1.39	39.10	0.30	28.75	6.0	
11. 10 t ha ⁻¹ PM+92 kg Nha ⁻¹	7.30	1.45	39.50	0.32	30.33	6.4	
12. 15 t ha ⁻¹ PM+92 kg Nha ⁻¹	7.35	1.50	41.54	0.35	33.24	7.0	

4.2. Phenology and growth parameters

4.2.1. Plant height

Highly significant difference ($P < 0.001$) in plant height was observed due to main effect of nitrogen fertilizer and poultry manure application as well as their interaction effects (Fig. 1). Numerically the maximum plant heights was observed from the application of 15 t ha⁻¹ of poultry manure with the mean values of (55 cm) followed by application of poultry manure at the rate of 10 t ha⁻¹ (54.66 cm) and 5 t ha⁻¹ (52.66cm). However, the lowest (49.33cm) plant height was recorded from 0 t ha⁻¹ of poultry manure application. The observed differences could be due to the difference in application rate of poultry manure in which increment in poultry manure especially in nitrogen availability enhances vegetative growth through increasing cell division and elongation. This result was in line with the findings of Farooq *et*

al. (2015), who reported an increase in height of plants with increased rate of application of organic fertilizers.

Application of Nitrogen fertilizer at the rate of 92 kg ha⁻¹ resulted with the tallest plant height (54.75cm) followed by 46 kg N ha⁻¹ while, the lowest plant height was recorded from the control treatment. The increase in height in response to increasing the rate of nitrogen may be ascribed to increased availability of nitrogen in the soil for uptake by plant roots that have enhanced vegetative growth through increasing cell division and elongation (Halvin *et al.*, 2003).

Similarly, Gubta and Sharma (2000) reported that increasing nitrogen rates increased plant height of onion. Nasreen *et al.* (2007) have also reported that an increase in the level of nitrogen to 160 kg ha⁻¹ increased plant height, while further increases tended to decrease the height. The result of the present study was also consistent with the findings of Aliyu *et al.* (2007), Mozumder *et al.* (2007), Nasreen *et al.* (2007) and Al-Fraihat (2009) who have reported liner increases in plant height with increasing rate of nitrogen application.

The interaction effects of poultry manure and nitrogen fertilizer application revealed that the highest value for plant height (56 cm) was recorded with the application of PM at a rate of 15 t ha⁻¹ with 46 and 92 kg N ha⁻¹. This is followed with the plant height obtained from the combined application of 10 t ha⁻¹ PM and 46 and 92 kg N ha⁻¹, followed by the combined use of 5 t ha⁻¹ PM and 46 and 92 kg ha⁻¹ N (54 cm). The lowest plant height was obtained from the control treatment (Fig. 1). The results of the interaction effect indicate that increasing the combination rate of nitrogen and poultry manure promotes plant growth. This may be attributed to the fact that poultry manure contains carbon, nitrogen and other essential

nutrients, which may have synergy with the inorganic nitrogen supply in promoting plant growth.

This result is in line with the findings of Reddy and Reddy (2005) who observed a significant increase in plant height of onion with increasing levels of vermicompost (from 10 to 30 t ha⁻¹) and N fertilizer (from 50 to 200 kg ha⁻¹). Similarly, Gonzalez *et al.*, (2001) have reported that organic manure and inorganic fertilizer supplied all the essential nutrients, resulting in increase of measured variables like plant height. Bwembya and Yerokun (2001) also reported significantly taller plants treated with both organic and inorganic fertilizers compared with the unfertilized plots.

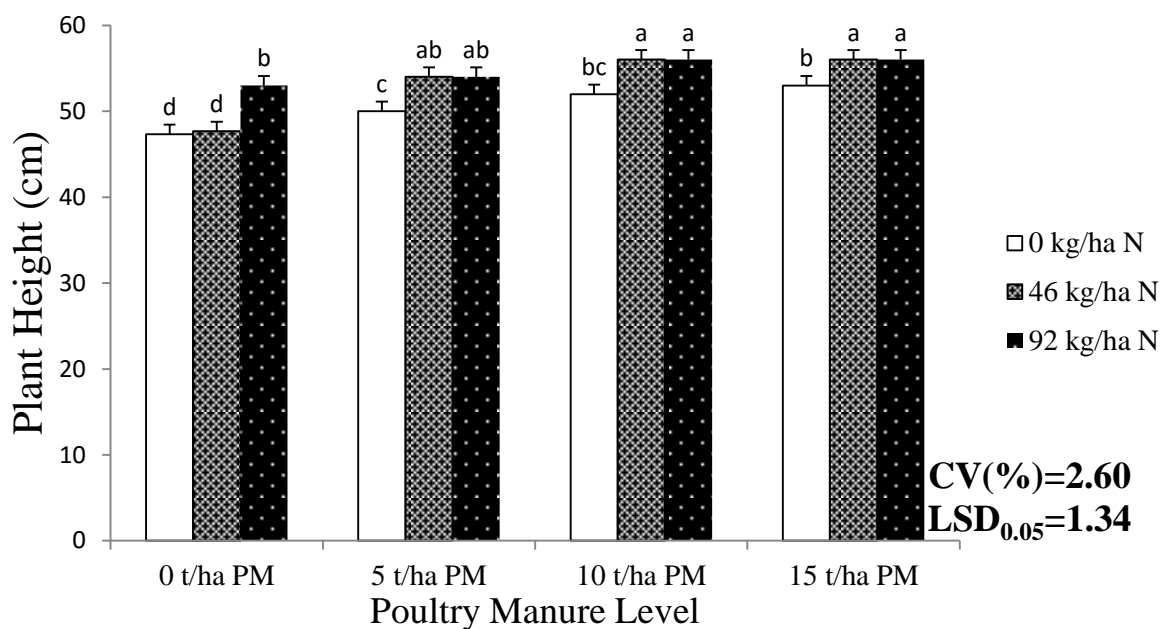


Figure 1. Interaction effects of poultry manure and nitrogen levels on plant height (cm) of onion grown at Alage, Ethiopia, during 2018 cropping season,

Means followed by the same letter are not statistically different from each other at 5% level of significant.

4.2.2. Number of leaves per plant

The leaf number of onion plants was significantly affected ($P < 0.001$) by application of poultry manure and application of nitrogen fertilizer ($P < 0.05$). However, it was not significantly affected by the interaction effect of those treatments (Appendix Table 1).

Application of poultry manure significantly increased the number of leaves per plant as compared to the control treatment (Table 4). The highest leaf number (12.55) was obtained from application of PM at the rate of 15 t ha^{-1} followed by 10 t ha^{-1} of PM (12.33). However, plants fertilized with 15 and 10 t ha^{-1} did not differ statistically with each other. The lowest leaf number (9.66) was recorded from unfertilized plants. The higher number of leaves per plant and plant height in the amended treatments over the control check could be attributed to increases in vegetative growth, resulting from the significant roles or effects of available essential plant nutrients in the synthesis of the different components of protein required for leaf development, photosynthesis and metabolic processes required for plant growth, thus enhancing rapid growth (Sekhon and Meelu, 1994).

In line with this, it has been reported that organic manures and inorganic fertilizers support a lot of vegetative growth as a result of high supply of nutrients, especially nitrogen (Singh *et al.*, 1989; Blay *et al.*, 2006). In agreement with the present study, it has been observed that application of FYM significantly affected the number of leaves of onion (Bashir *et al.*, 2015). Kokeb *et al.*, (2013) have also reported that application FYM has positively influenced leaf number of onion. Similarly, Khan *et al.*, (2002) have reported higher number of leaves per plant on plots treated with cow dung.

Regarding nitrogen rates, the highest leaf number per plant was obtained from the plots treated with 92 kg N ha⁻¹ (11.83), while the lowest value was recorded from plots with no nitrogen application (10.58). However, plants treated with nitrogen at the rate of 92 and 46 kg ha⁻¹ did not differ statistically with each other. The results of this study are similar to those observed by Abdissa and Tekalign, (2011), who reported that N fertilization (92 kg N ha⁻¹) significantly increased the number of leaves per plant and plant height of onion by 8% and 10%, respectively, over the control.

Vachhani and Patel (1993) and Nasreen *et al.*, (2007), have also found that application of 120-150 kg N ha⁻¹ significantly increased the number of leaves per plant for onion crop. The high number of leaves per plant recorded at higher dose of nitrogen may be attributed to the effect of nitrogen in the synthesis of proteins and enzymes which are essential for cell division and growth. The positive effect of nitrogen on vegetative growth is due to improved production and use of carbohydrates through photosynthesis, which is vital for growth and formation of new leaves (Jeyakumar *et al.*, 2007).

4.2.3. Leaf length

The analysis of variance of leaf length showed that main effects of PM had highly significant ($P < 0.001$) influence on leaf length of onion and also the main effects of N fertilizer had significant ($p < 0.05$) influence on leaf length of onion. However, it was not significantly affected by the interaction effect of those treatments (Appendix Table 1).

The study indicated that, statistically there were no significant differences observed among the treatments except with the control. The tallest leaf length was recorded from the application of 15 t ha⁻¹ of poultry manure with the mean value of (52.04 cm) followed by 10 t ha⁻¹ (51.66)

and 5 t ha⁻¹ (50.39) poultry manure application. While the shortest (45.70) leaf length was recorded from the unfertilized plants. As the result showed the leaf length was increased with increased poultry manure, this might be due to high nutrients content of the PM including nitrogen (Table 4).

The result supported by the observation of Mandal *et al.*, (2013) who reported an increase in length and number of leaves with the application of both organic and inorganic fertilizers. Organic manures and inorganic fertilizers support a lot of vegetative growth as a result of high supply of nutrients, especially nitrogen (Singh *et al.*, 1989; Blay *et al.*, 2006).

Application of nitrogen fertilizer at a rate of 92 kg ha⁻¹ resulted with the tallest leaf length 51.66 cm. while, the shortest leaf length was recorded on unfertilized onion plants. The leaf length response to nitrogen fertilizer is in agreement with Gubta and Sharma (2000), Ghaffoor *et al.*, (2003) and Jilani *et al.*, (2004) who reported that higher rates of nitrogen resulted in longer leaves of onion. Similarly, the present finding was in accordance with the finding of Sørensen and Grevsen (2001) and Kebede (2003) who reported that too much nitrogen promoted excessive vegetative growth (leaf length) in onion plant. The positive effect of N on leaf length may be due to the role it plays on chlorophyll, enzymes and proteins synthesis essential for vegetative growth (Halvin *et al.*, 2003) and also due to its enhancing effect on efficient uptake and utilization of phosphorus and other nutrients (Gustfson, 2010).

4.2.4. Days to maturity

Number of days to maturity of onion was significantly (P<0.001) affected by the main effects of nitrogen fertilizer and poultry manure application, but not significantly affected by the interaction effect of the treatments (Appendix Table 1). The present result showed that,

application of 15 t ha⁻¹, 10 t ha⁻¹ and 5 t ha⁻¹ poultry manure took relatively longer time for onion bulb to mature. Although there was significant difference between the two factors, the maximum number of days to maturity (113.66) was recorded from the plants treated with 15t ha⁻¹, followed by 10t ha⁻¹ poultry manure application (113.44), but the result from the two rates are not statistically different. While the earlier (108.77) days to maturity were taken by the untreated plants. The result indicates that the prolonged time required to reach maturity at higher level of poultry manure may be attributed to enhanced vegetative growth.

Days to maturity was significantly delayed (113 days) by the application of nitrogen fertilizer at the level of 92 kg ha⁻¹, followed by 46 kg ha⁻¹ N level; while plants from unfertilized plots matured earliest (109 days). The result indicates that the prolonged time required by the plants to reach maturity at higher rates of nitrogen fertilizers may be due to enhanced cell division and stimulation of vegetative growth which, as a result, delayed maturity of the plants. The current observation is in line with Brewster (1994), Sørensen and Grevsen (2001) and Kebede (2003) who reported that higher nitrogen levels resulted in excessive vegetative growth and delayed maturity. This result also supported by Ojala *et al.*, (1990) who reported that the application of higher nitrogen levels to potato promoted excessive vegetative growth and delayed maturity.

The results of this study also are similar to those observed by Marschner, (1995) and Gupta and Sharma, (2000), who reported prolonged vegetative growth of onion with the application of nitrogen and thus delayed plant maturity. This indicates that the nutrients taken up by plant roots used for increased cell division and synthesis of carbohydrate, which will predominantly be partitioned to the vegetative sink of the plants, resulting with a luxurious foliage growth of

plants (Marschner, 1995). Generally, plants grown under higher nitrogen rates tended to delay maturity (Table 4).

The result clearly indicated that days of maturity were prolonged in response to increased levels of poultry manure and mineral nitrogen fertilizer. This may be attributed to nitrogen contained in both fertilizers which prolonged the vegetative growth of onion.

Table 4. Main effects of poultry manure and nitrogen fertilizer rates on leaf length, leaf number and days to maturity of onion grown at alage, Ethiopia, during 2018 cropping season

Treatments	Leaf length(cm)	Leaf number	Days to maturity (day)
PM (t ha⁻¹)			
0	45.70 ^b	9.66 ^c	108.77 ^c
5	50.39 ^a	11.00 ^b	111.77 ^b
10	51.66 ^a	12.33 ^a	113.44 ^{ab}
15	52.04 ^a	12.55 ^a	113.66 ^a
LSD (5%)	2.16	1.12	1.77
N rate (kg ha⁻¹)			
0	48.95 ^b	10.58 ^b	109.75 ^c
46	49.23 ^b	11.75 ^a	112.16 ^b
92	51.66 ^a	11.83 ^a	113.83 ^a
LSD (5%)	1.87	0.97	1.53
CV (%)	4.42	10.12	1.62

Means followed by the same letter within a column or row are not statistically different from each other at 5% level of significant.

4.3. Yield and yield component parameters

4.3.1. Bulb length

Result from the analysis of variance revealed that the main effects of PM and mineral N fertilizer rates influenced the bulb lengths of onion. However, the two factors did not interact to influence bulb length (Appendix Table 2). The application of 15 t ha⁻¹ PM were produced the largest (4.28cm) bulb lengths followed by 10 t ha⁻¹ PM application (4.01cm) but, there were no significant difference observed between them. While the lowest bulb length was

recorded from the plant received zero PM, which mean from unfertilized plants. In this result with increasing application rates of poultry manure the bulb length also increased (Table 5).

In agreement with the present study, the use of organic fertilizer increased the length of onion bulbs as observed by Jayathilake *et al.*, (2003) and Akoun (2005). In contrast with the present study, Funda *et al.*, (2011) and Kokeb *et al.*, (2013) found that no difference in onion bulb lengths due to application of organic and mineral fertilizers. Brewster, (1994) report that this could be due to the fact that nitrogen is responsible for vegetative growth of plants rather than bulb length.

In the other hand, the application of 92 kg ha⁻¹ N fertilizer showed the largest bulb length (4.04cm) on onion, followed by 46 kg ha⁻¹ nitrogen application (4.00 cm), while the shortest bulb length were obtained from plants treated with no fertilizer. The analysis of variance showed that the application of nitrogen fertilizer at rate of 92 and 46 kg ha⁻¹ did not showed significance difference between them (Table 5).

The result agreed with observation of Kumar *et al.*, (1998) who reported that the highest bulb length was obtained from 150 kg N ha⁻¹. Similarly, Mozumder *et al.*, (2007) reported that bulb length significantly increased with the increases of nitrogen fertilizer up to 150 kg ha⁻¹. The longest bulb length with the increased application rates of nitrogen dose, may be due to higher synthesis of carbohydrates in the leaf and their translocation to the bulb, which comparatively helped in the increased length of onion bulbs (Neeraja *et al.*, 1999; Yadav *et al.*, 2003; Reddy and Reddy, 2005).

4.3.2. Bulb diameter

The main effects of poultry manure and nitrogen treatments as well as their interaction had significant effects on the bulb diameter of onion (Appendix Table 2). The main effect of poultry manure showed highly significant influence ($p < 0.001$) on bulb diameter. The effect of poultry manure indicated that plants treated with 15 t ha^{-1} PM had the highest bulb diameter (4.87cm) followed by 10 t ha^{-1} PM (4.72cm) and 5 t ha^{-1} PM (4.52cm) and plants treated with no PM had the shortest bulb diameter (3.87cm). Even though there is a difference between means of treatments; they were not statically different between 15 t ha^{-1} PM and 10 t ha^{-1} PM, and between 10 t ha^{-1} PM and 5 t ha^{-1} PM. The shortest bulb diameter at unfertilized plant might be due to the low level of nutrient in the soil which was essential for increasing bulb diameter. The present result were supported by the finding of Mandal *et al.*, (2013) and Brinjh *et al.* (2014) where an increase in organic manure application increased the bulb diameters. In confirmation to this study Wondye, (2017) reported that as the rates of FYM increased, the onion bulb diameters increased progressively up to some levels.

The effect of nitrogen significantly influenced the bulb diameter. The highest bulb diameter (4.70cm) was recorded from the plant treated with 92 kg ha^{-1} nitrogen followed by 46 kg ha^{-1} nitrogen (4.65cm) while the shortest (4.13 cm) bulb diameter was obtained from unfertilized plants. The analysis revealed that there was no statistical different between 92 and 46 kg ha^{-1} nitrogen application. The present result was supported by the finding of Wondye, (2017) who found that application of NPS fertilizer had a profound effect on bulb diameters of Adama red variety of onion. The current result showed that the bulb diameter was higher with application of higher doses of N, which may be attributed to highest synthesis of carbohydrate in the leaf and their translocation into bulb as reported by Halvin *et al.*, (2003). This might also be

ascribed to the role of N in promoting efficient utilization of other nutrients (Mengel and Kirby, 2001). The result also in agreement with that of Ghaffoor *et al.*, (2003), Yadav *et al.*, (2003), Jilani *et al.*, (2004), Mozumder *et al.*, (2007) and Nasreen *et al.*, (2007) who reported a significant increase in the diameter of onion bulbs due to the application of N ranging between 100 - 200 kg ha⁻¹. Similarly, Gubta and Sharma (2000) showed that increasing the nitrogen level significantly increased bulb diameter of onion.

With the interaction effect of poultry manure and nitrogen fertilizer the largest onion bulbs (5.10 cm) were recorded at the rate of 15 t ha⁻¹ poultry manure with 92 kg ha⁻¹ nitrogen application, but with no significant difference from those fertilized at 0,46 and 92 kg ha⁻¹ of nitrogen levels and received same rate of poultry manure (15 t ha⁻¹) and also there were no significant difference between the treatment at the rate of 10 t ha⁻¹ PM combined with 0, 46 and 92 kg ha⁻¹ N fertilizer, in addition those treatment combination were also no significant difference with the plant treated with the combination of 5 t ha⁻¹ PM combined with 46 and 92 kg ha⁻¹ nitrogen fertilizer application. The smallest bulb diameter (3.13cm) was recorded from the unfertilized plots. Under 0 kg ha⁻¹ of nitrogen fertilizer, bulb diameter notably increased as the poultry manure level increased, but no significant difference was produced between plants received 10 t ha⁻¹ and 15 t ha⁻¹ poultry manure. In 46 kg ha⁻¹ nitrogen level, increase in application of poultry manure up to 10 t ha⁻¹ significantly increased the diameter of onion bulbs; while further increase of nitrogen did not significantly alter bulb diameter (Fig 2). In agreement with the present study Metwally and Abdel-Bray (1999) recorded the smallest bulb diameter and average bulb weight in the control plot and attributed the higher values obtained in the combined application of organic and inorganic fertilizer to the role of organic manure in

improving soil structure, thereby reducing nutrient losses by leaching and deep percolation compared to application of inorganic fertilizer alone.

Similarly Jeyathilake *et al.*, (2006) have also reported increased bulb diameter weight on combined application of organic and bio fertilizers and linked it to accelerated synthesis of chlorophyll and amino acids, resulting in more translocation of photosynthesis from leaves to the bulbs translating to increased bulb and diameter of onions. Mondal *et al.*, (2004) reported increased onion bulb diameter and vitamin C content with combined application of organic manure and NPK fertilizer.

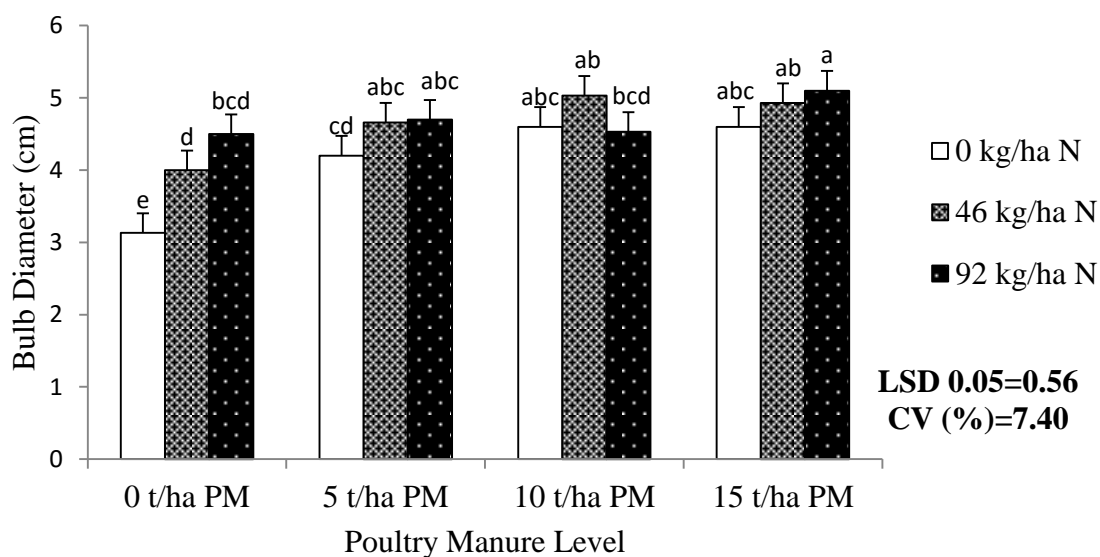


Figure 2. Interaction effects of poultry manure and nitrogen levels on the bulb diameter (cm) of onion grown at Alage, Ethiopia, during 2018 growing season.

Means followed by the same letter are not statistically different from each other at 5% level of significant

4.3.3. Average bulb weight

The main effect of poultry manure and its interaction with nitrogen fertilizer did not significantly influence average bulb weight of onion (Table 5) (Appendix Table 2). However,

the mineral nitrogen fertilizer in its main effects were significantly influenced ($P < 0.01$) the average bulb weights of onion.

The highest average bulb weight of onion were (52.16g) obtained by application of mineral nitrogen fertilizer at a rate of $92 \text{ kg ha}^{-1} \text{ N}$ followed (47.00g) by application of nitrogen at the rate of 46 kg ha^{-1} , even though the mean value between them is differ but statistically they were similar. While the lowest average bulb weight was recorded from the unfertilized plants (Table 5). The average bulb weight improvement in response to N could be attributed to the increase in leave number, leaf length and extended physiological maturity. The increase in leaf number and leaf length resulted in an increase in assimilate production and allocation to the bulbs (Kokobe *et al.*, 2013).

This finding with N fertilization was in agreement with the findings of Islam *et al.*, (2007) and Nasreen *et al.*, (2007) who reported that average bulb weight of onion significantly increased with increased nitrogen level up to $120 \text{ kg ha}^{-1} \text{ N}$. Similarly, Lemma and Shimeles (2003) have also reported that higher average bulb weight was obtained with application of 90 kg N ha^{-1} . Furthermore, Gubta and Sharma (2000) and Nasreen *et al.*, (2007) have also indicated that high nitrogen level increased bulb weight of onion. Similarly, Aliyu *et al.*, (2007) and Kokeb *et al.*, (2013) have found that application of $150 \text{ kg ha}^{-1} \text{ N}$ produced higher average fresh bulb weight compared to the lower doses of nitrogen.

The correlation analysis reviled that average weight of bulb was found to be positively and significantly correlated with bulb length ($r=0.54$), leaf number ($r=0.43$), plant height ($r=0.53$) and total biomass yield ($r=0.42$) indicating that N fertilization and poultry manure increased bulb weight by improving these parameters (Appendix Table 4). Abdissa *et al.*, (2011)

indicated that bulb weight had positively strongly association with plant height, leaf number and leaf length as affected by nitrogen and phosphorus fertilization.

4.3.4. Total biomass yield

Total biomass yield of onion which is the sum of all above and underground biomass was not significantly influenced by the main effects of PM and N fertilizer. Similarly, the interaction effects did not influence the total biomass yield of onion (Appendix Table 2). However regarding the poultry manure application, relatively the highest total biomass yield (74.33 t ha^{-1}) were obtained by the application of 15 t ha^{-1} PM, followed by 10 t ha^{-1} (73.77 t ha^{-1}) and 5 t ha^{-1} of PM (69.66 t ha^{-1}). While the lowest total biomass yield were recorded from the plant with no PM (Table 5). The total biomass yields of onion were relatively increased with generally increasing amount of poultry manure, which is in line with the finding of Melaku (2010) who reported that the application of 20 t ha^{-1} FYM increased the biological yield of onion by 33% compared to non fertilized controls. The increased yield and yield components due to the application of FYM are largely attributed to the improved soil organic matter, soil physical, chemical and microbial properties that enhance plant growth as well as nutrient availability and its uptake by the plants (Funda *et al.*, 2011).

Regarding nitrogen application the highest total biomass yield were obtained from the plants treated with $92 \text{ kg ha}^{-1} \text{ N}$ (75.66 t ha^{-1}) followed by $46 \text{ kg ha}^{-1} \text{ N}$ with the mean value of (69.91 t ha^{-1}) while the lowest were recorded from unfertilized plants (67.08 t ha^{-1}) (Table 5). The result was consistent with the finding of El-Tsntawy and El-Beik (2009) who reported the highest total biomass yield of onion at the application of higher rates of nitrogen. The total biomass yields were decreased with decreasing nitrogen application. The increase in biomass

yield in response to the increased N application may be ascribed to the predominant role that N plays in enhancing the physiological function of plants through promoting leaf expansion and photosynthesis (Balasubramaniyan and Planiappan, 2001).

The correlation analysis revealed that total biomass yield was found to be positively and significantly correlated with bulb diameter ($r=0.43^{***}$), bulb length ($r=0.52^{***}$) and leaf number ($r=0.40^*$). This implies that improving any of these parameters may lead to improvement in total biomass yield. (Fig. 3 and Appendix Table 4).

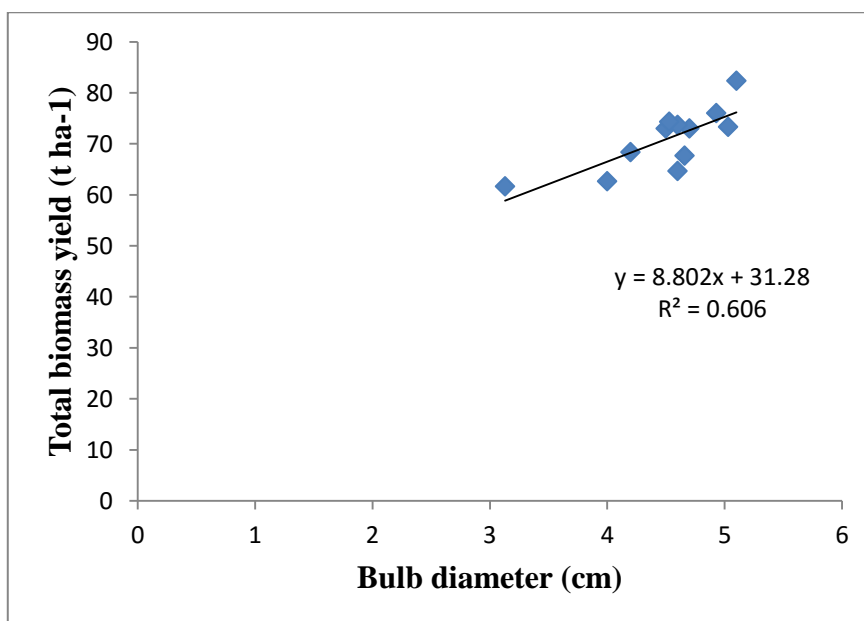


Figure 3. Relationship between total biomass yield and bulb diameter

4.3.5. Marketable bulb yield

The analysis of variance showed that PM was significantly influenced the marketable bulb yield of onion, but mineral N fertilizers and interaction effects were not significantly influenced the total bulb yield of onion (Appendix Table 2).

Highest marketable bulb yield of onion (62.52 t ha^{-1}) were obtained by the application of 15 t ha^{-1} PM followed by 10 t ha^{-1} (58.63 t ha^{-1}) and 5 t ha^{-1} PM (53.13 t ha^{-1}), While the lowest (52.40 t ha^{-1}) marketable bulb yield was recorded from the control plot. However, they no statistically difference was observed in yield between 15 t ha^{-1} and 10 t ha^{-1} and between 10 t ha^{-1} , 5 t ha^{-1} and 0 t ha^{-1} PM application. Satyanarayana and Prasad (2002) reported that organic manure plays an important role in improving soil permeability to air and water and water stable aggregates. Thus application of organic materials such as FYM considerably improves soil physical properties and nutrient uptake resulting in greater growth, yield and yield components. Akoun (2004) has shown that increasing the rate of manure application from 5.6 t ha^{-1} to 22.4 t ha^{-1} caused significant difference in yield. The highest yield of 9.55 t ha^{-1} was obtained with the application of 22.4 t ha^{-1} . Unlike chemical fertilizer that supplies only the major nutrients, FYM is a store house of several other plants nutrients and act as a good soil conditioner (Mishra and Nayak, 2004). In agreement with results of this study, Daniel (2006) also has shown that marketable potato tuber number was increased as the rates of both FYM and vermicompost increased from 5 to 10 t ha^{-1} and 4 to 8 t ha^{-1} , respectively.

The result of PM was supported by the finding of Wondye (2017) who reported that the application of 20 t ha^{-1} FYM on Bombay red increased the marketable yield by 21% compared to the respective control. Funda *et al.* (2011) also reported that the application of 20 t ha^{-1} organic manure increased onion yield. And Sankar *et al.* (2009) reported that increased marketable bulb yield of onion by the addition of organic manures, which was agreed with the present study. Ouda and Mahadeen (2008) reported that organic manures supplies nitrogen required for the multiplication of microorganisms and thus release of phyto-hormones which

may promote the growth and development of plants. Similar results also reported by Sharma *et al.* (2003) where they found increased onion yield due to the applications animal manure.

On the other hand, even though with the mineral nitrogen fertilizer the analysis of variance showed non-significance difference. However, relatively the highest (59.95 t ha⁻¹) marketable bulb yield of onion was obtained from the plots fertilized with 92 kg ha⁻¹ N followed by 46 kg ha⁻¹ (56.96 t ha⁻¹), while the lowest (53.10 t ha⁻¹) marketable bulb yield was recorded from the plants received 0 kg ha⁻¹N (Table 5).

The correlation analysis revealed that marketable bulb yield positively and significantly correlated with total bulb yield (r=0.99***), total biomass yield (r=0.57***), bulb diameter (r=0.53***) and bulb length (r=0.47**) (Appendix Table 4).

4.3.6. Unmarketable bulb yield

The analysis of variance revealed that PM and N fertilizers had significant effect unmarketable bulb yield of onion. However, no interaction effect of the factors was observed on unmarketable bulb yield of onion (Appendix Table 2). Based on the present result, highest unmarketable bulb yield (1.04 t ha⁻¹) in the case of poultry manure application were recorded from 0 t ha⁻¹ PM followed by 5 t ha⁻¹ PM (0.86 t ha⁻¹) and 10 t ha⁻¹ PM (0.83 t ha⁻¹) while the lowest was obtained from 15 t ha⁻¹ PM application (0.81 t ha⁻¹) (Table 5). The result showed that with increased poultry manure the unmarketable bulb yield were decreased. The present result was disagreed with the findings of Daniel (2006) who reported a decrease in unmarketable potato tuber number with a decreasing rate of FYM.

On the other hand unmarketable bulb yield was affected by the application of nitrogen fertilizer. Therefore, the highest (1.05 t ha⁻¹) unmarketable bulb yield were recorded from 0 kg

ha⁻¹ N followed by 46 kg N ha⁻¹ (0.84 t ha⁻¹) while the lowest were obtained by plants treated with 92 kg/ha N (0.76 t ha⁻¹) (Table 5). In confirmation with this study Brewster (1994) reported that under sub optimal supply of nitrogen, the marketable yield of onion and shallot can be severely reduced. Likewise, Jilani *et al.* (2004) indicated that nil nitrogen fertilizer rates resulted in more unmarketable bulb yield. In addition, in onion, low as well as lack of nitrogen fertilizer may have been associated with early bulb formation, stunted growth, with bulb size and marketable yields reduced (Kokeb *et al.* 2013).

Table 5. Main effects of poultry manure and mineral nitrogen fertilizer rates on average bulb length, bulb diameter, bulb weight; total biomass yield; marketable yield and unmarketable yield of onion grown at Alage, Ethiopia, during 2018.

Treatments	BL(cm)	ABW(g)	TBIY(t ha ⁻¹)	MBY(t ha ⁻¹)	UBY(t ha ⁻¹)
PM (t ha ⁻¹)					
0	3.27 ^c	40.88	65.77	52.40 ^b	1.04 ^a
5	3.87 ^b	46.66	69.66	53.13 ^b	0.86 ^b
10	4.01 ^{ab}	48.22	73.77	58.63 ^{ab}	0.83 ^b
15	4.28 ^a	49.33	74.33	62.52 ^a	0.81 ^b
LSD (5%)	0.32	Ns	Ns	7.63	0.13
N rate (kg ha ⁻¹)					
0	3.54 ^b	39.66 ^b	67.08	53.10	1.05 ^a
46	4.00 ^a	47.00 ^a	69.91	56.96	0.84 ^b
92	4.04 ^a	52.16 ^a	75.66	59.95	0.76 ^b
LSD (5%)	0.27	7.13	Ns	Ns	0.11
CV (%)	8.52	18.21	14.15	13.77	15.45

Means followed by the same letter within a column or row are not statistically different from each other at 5% level of significant. Where, BL=bulb length, BD=bulb diameter, ABW= average bulb weight, TBIY= total biomass yield, MBY= marketable bulb yield and UBY= unmarketable bulb yield.

4.3.7. Total bulb yield

The analysis of variance showed that the main effect of PM was significantly ($P < 0.05$) influenced the total bulb yield of onion, but mineral N fertilizers and interaction effects were not significantly influenced the total bulb yield of onion (Appendix table 2).

Generally, increasing application rate of PM produced highest total bulb yield. The highest total bulb yield (63.33 t ha^{-1}) were obtained by the application of 15 t ha^{-1} PM, while, the lowest (53.44 t ha^{-1}) total bulb yield were recorded from unfertilized onion plants (Table 6).

The results were agreed with the finding of Mia *et al.* (2007) who reported that the Plant height, total dry matter, single bulb weight, yield and nutrients uptake at different growth stages of onion varied significantly due to application of poultry manure and inorganic N fertilizer. The present study were also in line with the finding of Kokeb *et al.* (2013) who reported that the highest rate of total bulb yield increase with the application of FYM and mineral fertilizers. Another author reported that the application of 20 t ha^{-1} FYM increased the total bulb yield of onion by 24% compared to controls (Funda *et al.* 2011). The result in the present study are generally agreed with the findings of Sharma *et al.* (2003) who found animal manure applications increased onion yield. Similarly, Melaku (2010) reported an increase of 32.9% onion bulb yield compared to the control treatment. Ezekiel *et al.* (2014) reported the application of poultry litter at the rate of 15 t ha^{-1} produced the highest yield per hectare.

The finding of Diriba *et al.* (2015) reported that yield and yield attributes of garlic bulbs increased with the increases in the rates of nitrogen, phosphorus, and sulfur, which was also in line with to the present result of nitrogen application.

The correlation analysis revealed that the total bulb yield showed significant and positive correlation with total biomass yield ($r=0.56^{***}$), bulb diameter ($r=0.51^{**}$), bulb length ($r=0.46^{**}$), leaf number ($r=0.45^{**}$), plant height ($r=0.46^{**}$) and average bulb weight ($r=0.36^*$) this indicated that those parameters had contribution to total bulb yield, might be due to production of taller plants with higher number of leaves leading to increased photosynthesis and increased production of assimilates to fill the sink, which contribute to total bulb yield. However, total bulb yield was associated non-significantly positive with leaf length ($r=0.29$) and days to maturity ($r=0.32$) (Figure. 4 and Appendix Table 4).

Table 6. Main effects of poultry manure and mineral nitrogen levels on total bulb yield dry matter content and harvest index of onion grown at Alage, Ethiopia, during 2018.

Treatments	TBY ($t\ ha^{-1}$)	BDMC (%)
PM ($t\ ha^{-1}$)		
0	53.44 ^b	11.85 ^a
5	54.00 ^b	11.54 ^a
10	59.46 ^{ab}	9.84 ^b
15	63.33 ^a	8.70 ^c
LSD (5%)	7.68	1.11
N rate ($kg\ ha^{-1}$)		
0	54.15	11.78 ^a
46	57.80	10.62 ^b
92	60.72	9.04 ^c
LSD (5%)	Ns	0.96
CV (%)	13.65	10.85

Means followed by the same letter within a column or row are not statistically different from each other at 5% level of significant. Where, TBY=total bulb yield, BDMC=bulb dry matter content and HI= harvest index

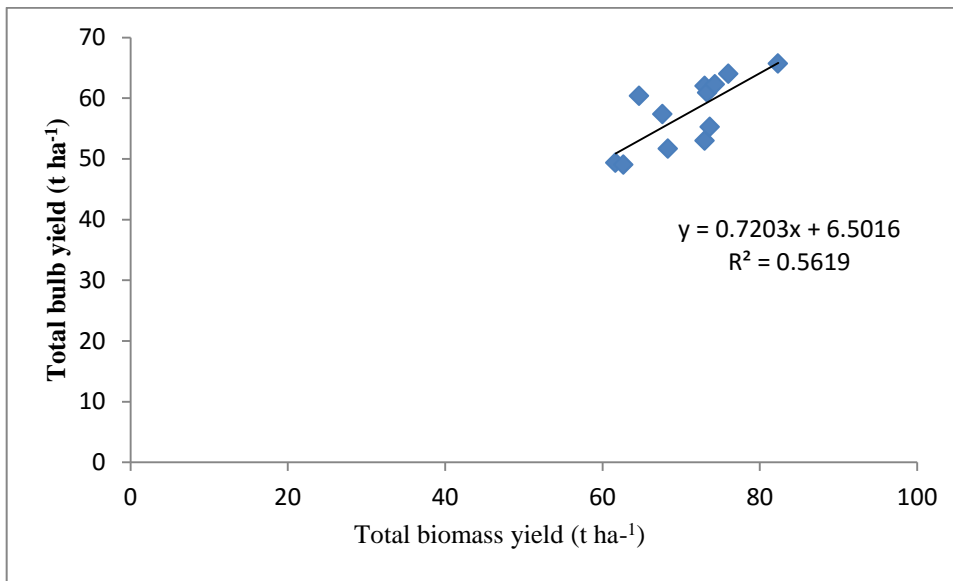


Figure 4. Relationship between total biomass yield and total bulb yield of onion

4.3.8. Bulb dry matter content

The analysis of variance showed that the main effects of PM and mineral N fertilizers were significantly influenced the bulb dry matter content. However, the interaction was not significantly influenced the bulb dry matter content (Appendix Table 2).

According to the present result, the highest (11.85 %) bulb dry matter content was recorded at the control plants and the lowest was recorded (8.7 %) at 15 t ha⁻¹ poultry manure application. It means that the more application of poultry manure the lower the bulb dry matter content (Table 6). The study was disagreed with the findings of Mia *et al.* (2007) who reported that the highest amount of dry matter content was recorded from the application of 57.5 kg ha⁻¹ N with 10 t ha⁻¹ poultry manure at all growth stages, the plants in the control treatment produced the lowest dry matter at all growth stages.

Regarding mineral nitrogen fertilizer application the highest (11.87%) bulb dry matter content was recorded from the plants treated with 0 kg N ha⁻¹ followed (10.62%) by 46 kg ha⁻¹ N while the lowest bulb dry matter (9.04%) was recorded from the nitrogen application at the rate of 92 kg N ha⁻¹. Similarly, bulb dry matter content decreased with increasing application rates of mineral nitrogen fertilizer (Table 6). In line with dry matter accumulation response to N application in this result, Maier *et al.* (1990) reported that dry matter of onion bulbs was not affected by nitrogen application. This result indicates that nitrogen fertilizer at lower rate would result in bulb with proportional dry matter content of onion. Patricia and Bansal (1999) also reported that nitrogen application had no effect on potato tuber dry matter. According to Brewster (1994), Sørensen and Grevsen (2001) excessive nitrogen resulted in a vigorous vegetative growth and reduced dry matter contents of onion bulbs.

4.3.9. Harvest index

Analysis of variance indicated that harvesting index was significantly influenced by the main effects of poultry manure and nitrogen fertilizer application as well as by their interaction effects (Appendix table 2).

The analysis of variance revealed that the main effects of poultry manure application had significant ($p < 0.001$) influence on harvest index. With poultry manure application the highest (81.55%) harvest index were recorded at the rate of 15 t ha⁻¹ PM followed by 10 t ha⁻¹ PM (80.44%) and at 5 t ha⁻¹ (73.55%) while the lowest were recorded at 0 t ha⁻¹ PM (71.77%) application

The highest harvest index (80.00%) were obtained from 92 kg N ha⁻¹, while the lowest harvest index (72.16%) was recorded from 0 kg ha⁻¹ N application. This result was supported by the finding of Abdissa (2008) who observed that harvest index of onion increased with increasing nitrogen rate up to 115 kg ha⁻¹ compared to the control. This could be attributed to improved photosynthetic capacity of plants and movement of assimilates from the leaves to the bulbs during the growing period.

The interaction effects of poultry manure and nitrogen fertilizer had significantly affected the harvest index of onion. Therefore, a harvest index of (86.66%) was obtained from poultry manure application at the rate of 10 t ha⁻¹ with 92 kg ha⁻¹ of nitrogen fertilizer, which were the highest one among all combination of PM and N application while the lowest was recorded from unfertilized plants. However there were no significant differences were observed between the treatment rate of 10 t ha⁻¹ PM combined with 92 kg N ha⁻¹, 15 t ha⁻¹ PM combined with 46 kg N ha⁻¹ and 15 t ha⁻¹ PM combined with 92 kg N ha⁻¹ fertilizer application (Figure 5).

The result were in line with the finding of Tadila (2011) who reported the application of 50 kg N ha⁻¹ combined with 10 t ha⁻¹ manure showed maximum harvest index of garlic. This finding is also supported by the results of Wondimu (2009) who reported that the highest harvest index for Adama Red cultivar of onion was recorded from treatments that received N and FYM at 25 kg N ha⁻¹ + 8 t FYM ha⁻¹.

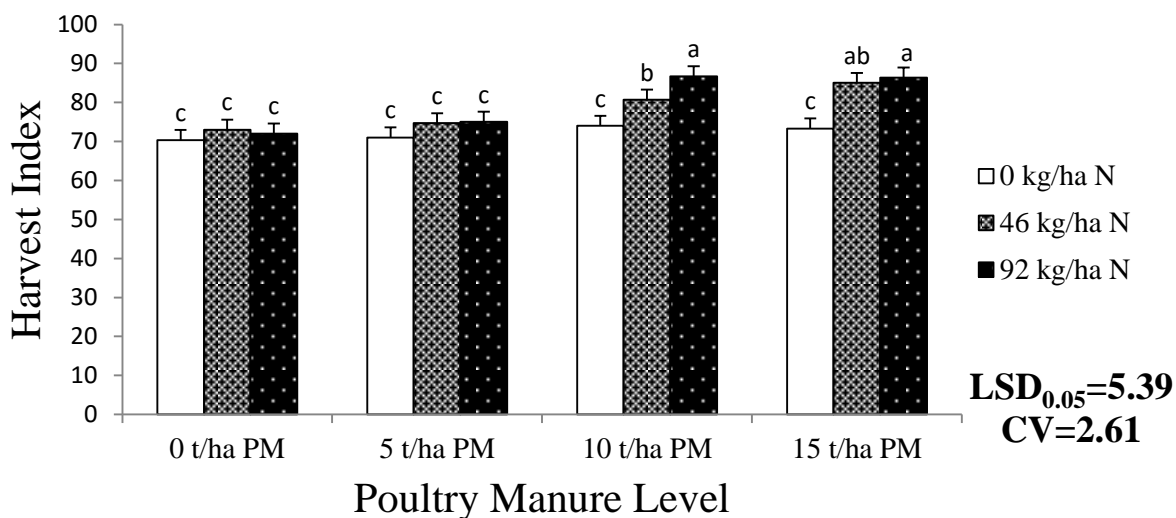


Figure 5. Interaction effects of poultry manure and nitrogen levels on harvest index of onion grown at Alage, Ethiopia, during 2018.

Means followed by the same letter are not statistically different from each other at 5% level of significant.

4.4. Partial budget analysis

The economic analysis was done for only poultry manure application, where significant variation was observed. Partial budgeting is a method of organizing experimental data and information about the costs and benefits of various alternative treatments. According to CIMMYT (1988), the average yield was adjusted downward by 10% in order to represent the yield obtained by the farmers as compared to that of the research. In line with this, the analysis revealed that the highest gross field benefit (450,080 ETB ha⁻¹) and net benefit (430,580 ETB ha⁻¹) were obtained from 15 t ha⁻¹ PM application, whereas the lowest gross field benefit (377,280 ETB ha⁻¹) was recorded for the control plot and the lowest net benefit (375,980 ETB ha⁻¹) was obtained from 5 t ha⁻¹ PM. The dominance analysis indicated that application of only 5 t ha⁻¹ PM was dominated and thus, further marginal rate of return analysis was not considered for the treatment.

The analysis of marginal rate of returns (MRR) for this experiment revealed that treatment that received 10 t ha⁻¹ and 15 t ha⁻¹ PM have given a marginal rate of return above the minimum acceptable rate (100%). The highest marginal rate of return of 6624% was obtained from 15 t ha⁻¹ PM fertilizer, indicating that for every 1.00 ETB invested for application of 15 t ha⁻¹ PM in the field, producers can obtain an additional benefit of 66.24 ETB. Poultry manure application at the rate of 10 t ha⁻¹ exhibited the second most promising result with 3146% marginal rate return and net benefit of 409,080 ETB ha⁻¹. This MRR analysis indicated that farmers at the study area need to use 15 t ha⁻¹ PM in order to maximize their profitability.

Table 7. Partial Budget Analysis for poultry manure application at Alage.

	Treatment			
	0 t ha ⁻¹	5 t ha ⁻¹	10 t ha ⁻¹	15 t ha ⁻¹
Average yield (t ha ⁻¹)	52.40	53.13	58.63	62.52
Adjusted yield (t ha ⁻¹)	47.16	47.81	52.76	56.26
Gross benefits ETB ha ⁻¹	377,280	382,480	422,080	450,080
Labour cost for poultry manure application ETB	0	1500	3000	4500
Poultry manure cost ETB ha ⁻¹	0	5000	10,000	15,000
Total cost that vary ETB ha ⁻¹	0	6500	13000	19500
Net benefits ETB ha ⁻¹	377,280	375,980D	409,080	430,580

Where, ETB= Ethiopian Birr (currency); price for poultry manure= 1.00 ETB kg⁻¹

Table 8. Analysis of Marginal rate of return for poultry manure application at Alage.

PM (t ha ⁻¹)	Total variable cost (Birr ha ⁻¹)	Marginal cost (Birr ha ⁻¹)	Net benefit (Birr ha ⁻¹)	Marginal net benefit (Birr ha ⁻¹)	Marginal rate of return (%)
0	0	-	377,280	-	-
10	13000	13000	409,080	31.46	3146
15	19500	6500	430,580	66.24	6624

5. SUMMARY AND CONCLUSION

Onion (*Allium cepa* L.) is a widely recognized cash crop, successfully produced under rain fed as well as irrigated conditions in different parts of Ethiopia. The area under onion production in the country is increasing from time to time. Despite the increase in area coverage, the productivity of the crop is much lower due to biotic and abiotic factors. However, lack of information on appropriate fertilizer type and rates, declining soil fertility and limited water availability are the most important factors attributing for the low yield of onion. This study was, therefore undertaken to assess the effect of different rates of poultry manure and nitrogen fertilizer on growth, quality and yield of onion and to identify economically feasible rates of poultry manure.

The experiment was carried out at Alage Agricultural Technical and Vocational Education and Training College (Alage) campus, Central Refit Valley of Ethiopia during 2018/19 season. The experiment comprised three levels of nitrogen fertilizer (0.46 and 92 kg N ha⁻¹) and four levels of poultry manure (0, 5, 10 and 15 t ha⁻¹) using RCBD with three replications. The soil physical and chemical properties of experimental site were analyzed before and also after harvesting, Data were collected on phenological and growth parameters, yield and yield components of onion.

The relevant data collected were subjected to analysis of variance using SAS software and significant treatment means were compared using least significant difference (LSD) test at 5% probability level.

The main effects of poultry manure and nitrogen fertilizer levels significantly affected most plant growth and bulb yield characters of onion. Plant height, leave number per plant, leaf

length, days to maturity, bulb length, bulb diameter and harvest index were increased as the poultry manure and nitrogen fertilizer increased while the unmarketable bulb yield and bulb dry matter content were significantly reduced with increased poultry manure and nitrogen fertilizer levels.

The main effects of poultry manure alone significantly affected total bulb yield and marketable bulb yield of onion, On the other hand, average bulb weight was significantly affected by sole application of nitrogen fertilizer. The interaction of poultry manure with nitrogen fertilizer were significantly affected the plant height, bulb diameter and harvest index of onion at the study area.

Plant height showed increasing trend with increased level of PM and N fertilizer. Days to maturity showed increasing trend as the nitrogen and poultry manure rate increased. However, the analysis of variance showed that at 10 t ha⁻¹ and 15 t ha⁻¹ poultry manure level did not vary significantly in days to maturity, while the bulb dry mater content and unmarketable bulb yield were significantly reduced with increased fertilizer application.

Similarly, the longest leaf length (52.04 cm), leaf number per plant (12.55) and bulb length (4.28 cm) were obtained from the poultry manure application at 15 t ha⁻¹. However, lowest leaf length (45.70 cm), leaf number per plant (9.66) and bulb length (3.27 cm) were recorded from the unfertilized plants. The total and marketable bulb yield was increased with increasing poultry manure application, but sole application of nitrogen fertilizer not affected the total and marketable bulb yield.

Correlation analysis indicated that marketable bulb yield positively correlated with most of growth parameters. The partial budget analysis revealed that highest gross field benefit

(450,080 ETB ha⁻¹) and net benefit (430,580 ETB ha⁻¹) was obtained from 15 t ha⁻¹ PM application, whereas the lowest gross field benefit (377,280 ETB ha⁻¹) was recorded from the control plot and the lowest net benefit (375,980 ETB ha⁻¹) was obtained from 5 t ha⁻¹ PM. The dominance analysis indicated that only 5 t ha⁻¹ PM application rate was dominated and further marginal rate of return analysis was not considered for the treatment. The analysis of marginal rate returns (MRR) for this experiment revealed that treatment that received 10 t ha⁻¹ and 15 t ha⁻¹ PM application had given a marginal rate of return above the minimum acceptable rate (100%).

Therefore, it was concluded that yield of onion variety Bombay Red could be substantially increased through poultry manure application. Based on the result of the current study application of poultry manure at the rate of 15 t ha⁻¹ was numerically provided the highest growth and yield related characters of onion. Moreover, the highest rate of return was obtained from the use of the same rates of PM. Therefore, PM application of 15 t ha⁻¹ can be recommended for optimized yield and economic benefits of onion for the study area and similar agro-ecologies. However, since this experiment is conducted for a single location and year, over location and year research is warranted to confirm the present results.

6. REFERENCE

- Blandari A.L., K.N. Sharma, M.L. Kapur, and D.S. Rana.1989. Supplementation of nitrogen through green manuring for maize growing. *Journal of Indian Society of Soil Science* 37:- 483 – 486
- Abbey, L. and D.C Joyce. 2004. Water deficit stress and soil type effects on spring onion accumulation and partitioning in two potato cultivars. *Journal of Plant nutrition*, 25:1621-1630.
- Abdelrazzag A. 2002. Effect of chicken manure, sheep manure and inorganic fertilizer on yield and nutrients uptake by onion. *Pak. J. Biol. Sci.* 5: 266–268.
- Abdissa Yadeta, Tekalign Tadesse and L.M. Pant. 2011. Growth, bulb yield and quality of onion (*Allium cepa* L.) as influenced by nitrogen and phosphorus fertilization on vertisol I. growth attribute biomass production and bulb yield. *African J. Agric. Res.*, 6(14): 3252-3258.
- Abdissa Yohannes. 2008. Effects of nitrogen and phosphorus rates on growth, yield, quality and storability of onion (*Allium cepa* L.) on vertisols of Shewa Robit. M.Sc thesis presented to Haramaya University, Ethiopia.
- Abou el Magd MM, Hoda Mohammed A, Fawz ZF. 2005. Relationship Growth and Yield of Broccoli with increasing N, P or K Ratio in a Mixture of NPK fertilizers. *Annals of Agricultural Science, Moshtohor Journal* 43(2):791–805.
- Adekiya, A.O. and Agbede, T.M. 2009. Growth and yield of tomato (*Lycopersicon esculentum* Mill) as influenced by poultry manure and NPK fertilizer Emir. *Journal of Food Agriculture*. 21(1): 10-20.
- Adesodun, J.K., Mbagwu, J.S.C. and Oti, N. 2005. Distribution of carbon nitrogen and phosphorus in water stable aggregates of an organic waste amended ultisol in southern Nigeria. *Bioresource Technol.* 96: 509-516.
- Adu Boakye. 2011. Effect of soil amendments and botanicals on the performance of spring onions (*Allium Fistulosum* L.) and control of onion thrips (thrips tabaci). M.Sc thesis presented to Kwame Nkrumah University, Ghana.
- Aklilu, S. 1997. Onion research and production in Ethiopia. *Acta Horticulturae* 433, 95-97.
- Akoun J. 2005. Effect plant density and manure on the yield and yield components the common onion (*Allium cepa* L.) var. Nsukka red. *Hort Sci.* 9: 43-48.
- Akuon, J., 2004. Effect of plant density and manure on yield and yield components of common onion (*Allium cepa* L.) Var. Nsukka Red. *Nigerian J. Hort. Sci.*, 9: 43–48.
- Al-Fraihat, H. Ahmad. 2009. Effect of different nitrogen and sulphur fertilizer levels on growth, yield and quality of onion (*Allium cepa* L.). *Jordan Journal of Agriculture science*, 5(2): 155-165.

- Ali Baghdadadi, Ridzwan A. Halim, Ali Ghasemzadeh, Mohd Fauzi Ramlan and Siti Zaharah Sakimin. 2018. Impact of organic and inorganic fertilizers on yield and quality of silage corn intercropped with soybean. Research, University of Malaysia.
- Aliyu, L. 2003. Effect of manure type and rate on the growth, yield and yield component of pepper (*Capsicum annum L.*). *J. Sustain. Agric. Environ.*, 5: 92–8
- Aliyu,U., M.D. Magajj, A. Singh and S.G. Mohammed. 2007. Growth and yield of onion (*Allium cepa L.*) as influenced by nitrogen and phosphorus levels. *International Journal of Agriculture Research*, 2: 937-944.
- Aluko, O.B. and Oyedele, D.J, 2005. Influence of organic incorporation on changes in selected soil physical properties during drying of a Nigerian alfisols. *Journal of Applied Science* 5:357-362.
- Awodun, M.A. 2007. Effect of poultry manure on the growth, yield and nutrient content of fluted pumpkin (*Telfaria occidentalis Hook F.*). *Asian Journal of Agriculture Research* 1: 67-73.
- Bagali, A.N. Patil, H.B. Guled, M.B. and Patil, R.V. 2012. Effect of scheduling of drip irrigation on growth, yield and water use efficiency of onion (*Allium cepa L.*). *Journal of Agricultural Science*, 25 (1):116-119.
- Balasubramanian, P. and S. P. Palaniappan. 2001. Nutrient management. In: Principles and practices of agronomy. *Agrobios, India*. P-185-188
- Bary A.I., C.G. Cogger, and D.M. Sullivan. 2000. Fertilizing with manure. Washington State Univ. Coop. Ext., Pacific Northwest Ext. Publ. 533.
- Baset Mia M.A, Sandjida Akter, Mola A.H and Mustafizur Rahman G.K.M. 2007. Poultry manure with inorganic nitrogen on growth and yield of onion (*allium cepa L.*) in Bangabandhu Sheikh Mujibur Rahman Agricultural University, Gazipur, Bangladesh. *A scientific journal of krishi foundation. The agriculturists* 5(1&2):101-108).
- Bashir A. Y, Liman Y. M & Zangoma I. M. 2015. Effect of Different Source of Organic Manure on the Growth and Yield of Irrigated Onion in Damaturu Local Government Area of Yobe State, Nigeria. *International Journal of Multidisciplinary Academic Research* Vol. 3, No. 4, ISSN 2309-3218.
- Bassett, M.J. 1986. Breeding vegetable crops. AVI Publish. Co. Inc. West Port, Conecticut. 584p.
- Bezabih Eman, Victor Afari-Sefa, Fekadu F.Dinssa, Amsalu Ayana, Tesfaye Balemi and Milkessa Temesgen. 2015. Characterization and Assessment of Vegetable Production and Marketing Systems in the Humid Tropics of Ethiopia. *Quarterly Journal of International Agriculture* 54, No. 2: 163-187.

- Blay ET, Danquah EY, Ofosu-Anim J, Ntummy JK. 2006. Effects of poultry manure and/or inorganic fertilizer on the yield of shallot (*Allium cepa* var. *aggregatum*). *Advance Horticulture Science*. 16(1):7-12.
- Bosch Seera, A.D. and Currah L., 2002. Agronomy of onions. In: Rabinowitch H.D and L. Currah(ed). *Allium crop science: recent advance*. CABI, Walling Ford, UK. Pp 87-223.
- Boukary H, Haougui A, Barage M, Adam T, Roumba A, et Saadou M. 2012. Evaluation agromorphologique des varietes et/ou ecotypes locaux d'oignon du Niger. *Int J Biol Chem Sci* 6(6):3098-3106.
- Boyhan G.E., R.J. Hicks, R.L. Torrance, C.M. Riner, and R. Hill. 2010. Evaluation of poultry litter and organic fertilizer rate and source for production of organic intermediate-day onions. *HortTechnology* 20:304–307.
- Brewster J.L. 1994. Onions and other vegetable Alliums. CAB International, Wallingford, UK.
- Brewster J.L. 1990. Cultural systems and agronomic practices in temperate climates, p.1-30.
- Brewster, J. L. and H.A. Butler. 1989. Effects of nitrogen supply on bulb development in onion. *Journal of experimental Botany*, 40: 1155-1162.
- Brinjh S., Kumar, S., Kumar, D. and Kumar, M. 2014. Effect of integrated nutrient management on growth, yield and quality in onion, cv.Pusa Madhavi, *Plant Archives*, 14, 557-559.
- Bwembaya, S., and O.A. Yevokun, 2001. Effects of Cassia spectabilis, cowdung and their combination on growth and grain yield of maize. Seventh Easter and Southern Africa Regional Maize Conference, 11th-15th February 2001. pp.361-366.
- Casey, K.D., Bicudo, J.R., Schmidt, D.R., Singh, A., Gay, S.W., Gates, R.S., Jacobsen, L.D. and Hoff, S.J. 2006. Air quality and emissions from livestock and poultry production/waste management systems, in: Rice, J.M., Caldwell, D.F. & Humenik, F.J. (Eds.) *Animal Agriculture and the Environment: National Center for Manure and Animal Waste Management White Papers*, Publication No 913C0306, pp. 1-40 (St. Joseph, MI, ASABE).
- CFA (California Fertilizer Association). 1995. *Western Fertilizer Hand Book*. p.89.
- Chater M, Gasser JKR. 1970. Effects of green manuring, farmyard manure, and straw on the organic matter of soil and of green manuring on available nitrogen. *Journal of Soil Science* 21(1):127–137.
- CIMMYT. 1988. *from Agronomic Data to Farmer Recommendations: An Economics Training Manual*. Completely revised edition. Mexico. D.F.

- Connor, D.J., A.J. Hall and V.O. Sadras. 1993. Effect of nitrogen content on the photosynthetic characteristics of sunflower leaves. *Australian Journal of Plant Physiology*, 20: 251-263.
- Corgan J., M. Wall, C. Cramer, T. Sammis, B. Lewis and J. Schroeder. 2000. Bulb onion culture and management. *Agricultural Experiment Station Circular*, 563: 1-16.
- Cottenie I. 1980. Soil and plant testing as a base for fertilizer recommendation. FAO soils bulletin No. 38/2, FAO, Rome, Italy. 220p.
- CSA. 2016. Area and production of major crops. Agricultural sample survey 2015/2016, private peasant holdings, Meher season, Statistical Bulletin 584, Addis Ababa, Ethiopia.
- CSSE (Crop Science Society of Ethiopia). 2006. Farmers' participatory onion seed production in the Central Rift Valley of Ethiopia: achievement, constraints and its implication for the national seed system. Conference summary, The Conference of the Crop Science Society of Ethiopia, 11, Addis Abeba (Ethiopia), 26-28 Apr 2004.
- Dada, O. A. and Fayinminnu, O. O. 2010. Influence of cattle dung and weeding regimes on period of weed control in okra. *Not. Bot. Hort. Agrobot. Cluj*. 38(1) 149-154.
- Dalzell, H.W., A.J. Biddleste, K.R. Gray and K.Thurairajan, 1987. Soil compost: compost production and use in Tropical and sub-tropical environments. FAO soils bulletin 56. pp.117-118.
- Daniel Mekonnen, 2006. Effects of integrated nutrient management on agronomic performance of potato (*Solanum tuberosum. L.*) and fertility of nitosol at Bako. (Unpublish MSc. thesis), Alemaya University, Ethiopia.
- Dauda, S.N., Ajayi, F.A. and Ndor, E. 2008. Growth and Yield of Watermelon (*Citrullus lanatus*) as Affected by Poultry Manure Application. *Journal of Agriculture and Social Sciences*, 4: 121–124
- Decoteau D. R. 2000. Vegetable Crops. Prentice-Hall, Inc. USA. 561p.
- Desalenge L. and Aklilu S. 2003. Research Experiences in Onion Production, EARO Ethiopian Agricultural Research Organization, Research Report No 55.no ISBN.
- Dikinya, O. and Mufwanzala, N. 2010. Chicken manure enhanced soil fertility and productivity: Effects of application rates. *Journal of Soil Science and Environmental Management*. 1(3): 46-54.
- Diriba Shiferaw, Nigussie Dechassa, Kebede Woldetsadik, Getachew Tabor and Sharma J.J. 2015. Effect of Nitrogen, Phosphorus, and Sulphur Fertilizers on Growth, Yield, and Economic Returns of Garlic (*Allium sativum L.*). *Science, Technology and Arts Research Journal* 4(2): 10-22.

- Drost D. and Koenig R. 2001. Improving Onion Productivity and N Use Efficiency with a Polymer Coated Nitrogen Source. Utah State University, Department of Plants, Soils and Biometeorology: Logan, UT 84322-4820.
- Dudal R, Roy R. 1995. Integrated nutrition systems. Report of an expert consultation held in Rome Italy, 13–15 Dec 1993. FAO Fertilizer and Plant Nutrition Bulletin.
- EARO (Ethiopian Agricultural research Organization), 2004. Released crop varieties and their recommended cultural practices. Progress report. Addis Ababa, Ethiopia.
- Eifediyi, E. K. and Remison, S. U. 2010. Growth and yield of cucumber (*Cucumis sativum L.*) as influenced by farm yard manure and inorganic fertilizer. *Journal of Plant Breeding and Crop Science* 2(7): 216-220.
- El-Tantaway and El-Beik. 2009. Relationship between growth, yield and storability of onion with fertilization of nitrogen, sulphur and copper under calcareous soil conditions. *Research Journal of Agriculture and Biological Sciences*, 5(4): 361-371.
- Ethiopia Horticulture Development Agency (EHDA), 2011. Assessment of development potentials and investment options in the export –oriented fruit and vegetable sector. Exporting fruit and vegetable forum Ethiopia. March, 2011.
- Ewulo, B.S., Ojeniyi, S.O. and Akanni, D. A. 2008. Effect of poultry manure on selected soil physical and chemical properties, growth, yield and nutrient status of tomato. *African Journal of Agricultural Research* Vol. 3 No. 9: pp. 612-616.
- Eylachew Zewdie, 2004. characterization and genesis of some soils of Ethiopia rift valley showing undic properties. *Ethiopia soc. of soil sc.* 6(1): Pp. 215-235.
- Ezekiel Y. G., Gambo, B. A. and Kabura, B. H. 2014. Effect of organic manures and irrigation intervals on the growth and yield of onion (*Allium cepa L.*) in Central and Southern Borno State, Nigeria. *International Journal of Advance Agricultural Research* 2, 106-111. ISSN 2053-1265.
- FAOSTAT. 2013. Crop download. Available:
- Farooq M., Shah, A.H., Malik, A., Niaz, A., Uzma, K., Abdul M. and Habib, A. 2015. Nutrient Management for Improving Onion Productivity, *American-Eurasian J. Agric. & Environ. Sci.*, 15: 220-225.
- Fekadu Melesse and Dandena Gemechu. 2006. Review of the status of vegetable crops production and marketing in Ethiopia. *Uganda Journal of Agricultural Sciences* 12(2): 26-30.
- Figueiredo MDVB, Junio MDAL, Messias AS, Menezes RSC. 2009. Potential impact of biological nitrogen fixation and organic fertilization on corn growth and yield in low external input systems. In: Danforth AT, ed. Corn crop production growth, fertilization and yield. *New York: Nova Science Publisher*, 227–255.

- Food and Agricultural Organization (FAO). 2010. FAOSTAT data, 2010. www.FAO.org.
- Food and Agricultural Organization (FAO). 2012. Statistical Yearbook. Food and Agriculture Organization (FAO), Rome, Italy.
- Food and Agricultural Organization (FAO). 2013. Statistical Yearbook. Food and Agriculture Organization (FAO), Rome, Italy.
- Friend, A.L., Roberts, S.D., Schoenholtz, S.H., Mobley, J.A. and Gerard, P.D. 2006. Poultry litter application to Loblolly pine forests: Growth and nutrient containment. *Journal of Environmental Quality* 35: 837-848.
- Funda Y., C. Safak, M. Nilgun and C. E. Bihter. 2011. Effect of organic and inorganic fertilizers on yield and mineral content of onion (*Allium cepa* L.), *African Journal of Biotechnology*, 21 September, 2011, Vol. 10 (55), pp. 11488-11492.
- Gambo, B. A., Magaji, M. D., Yakubu, A. I. and Dikko, A. U. 2008. Effects of Farm yard Manure and weed interference on the growth and yield of onion (*Allium cepa* L.). *Journal of sustainable Agriculture and Environment* 3(2): 87-92.
- Geremew Awas, Teshome Abdisa, Kasaye Tolesa and Amenti Chali. 2010. Effect of intra-row spacing on yield of three onion (*Allium cepa* L.) varieties at Adami Tulu agricultural research center (mid rift valley of Ethiopia). *J. Hort. & Forestry*, 2(1): 007-011.
- Ghaffoor, A., M.S. Jilani, G. Khaliq and K. Waseem . 2003. Effect of different NPK levels on the growth and yield of three onion varieties. *Asian Journal Plant sciences*, 2: 342-346.
- Gonzalez, D.R., J. Alvarez and J. Matheus, 2001. Comparison of organic fertilizers for the production of sweet corn. Proceedings of the Inter American Society for Tropical Horticulture, 45:106-109.
- Gonzalez D, Alvarez R, Matheus J. 2001. Comparison of three organic fertilizers for the production of sweetcorn (*Zea mays saccharata*). In: Proc. Inter American Society for Tropical Horticulture. vol. 45. 106–109.
- Grubben, J.H. and Denton, D.A. 2004. Plant Resources of Tropical Africa. PROTA Foundation, Wageningen; Backhuys, Leiden, CTA, Netherlands.
- Gubb I.R and M.S.H. Tavis. 2002. Onion pre-harvest and postharvest considerations. In: H.D. Rabinowitch, and L. Currah (Eds.). Allium Crop science. CABI publishing, UK. pp. 237-250.
- Gubta, R.P. and CV.P. Sharma. 2000. Effects of different spacing and levels of nitrogen for production of export quality onion bulbs planted on raised bed. *News letter- National Horticultural Research and Development Foundation*, 20: 1-16.
- Gustafson, A.A. 2010. Hand book of fertilizers, their source, makeup, effect and use (3rd ed). Agrobios, Indian. pp. 78-88.

- Isitekhale H.H.E, and Osemwota I.O.. 2010. Residual effects of poultry manure and NPK fertilizer on nutrient contents and uptake by tomato in the forest and derived savanna soils of Edo State. *Nigerian Journal of Soil Science*, Vol. 20(2), 17-25.
- Halvin, J. L., D.B. James, L.T.Samuel and L.N.Warner. 2003. Soil fertility and fertilizers an introduction to nutrient management (6th Ed.). Pearson Education Inc., New Delhi, India. pp.752-760.
- Halvorson, A.D., Follet, R.F., Bartolo, M.E. & Schwessing, F.C. 2002. Nitrogen fertilizer use efficiency of furrow-irrigated onion and corn. *Journal of Agronomy*, 94: 442-449.
- Horneck D.A., D.M. Sullivan, J.S. Owen, and J.M. Hart. 2011. Soil Test Interpretation Guide. Oregon State University, EC 1478.
- ICAR (Indian Council of Agricultural Research). 2011. Directorate of onion and garlic research. Http: /www.dogr.res.in.
- Ishak, C. F., Bakar, R. A., Saud, H. M. and Abdullah, T. L. 1999. Application of sewage sludge from Indan water treatment plants. *Agro Search*, 6 (1): 14 – 19.
- Islam M. K., M. F. Alam and A. K. M. R. Islam. 2007. Growth and yield response of onion (*Allium cepa* L.) genotypes to different levels of fertilizers. *Bangladesh Journal of Botany*, 36: 33-38.
- Jayathilake P. K. S.; I. P. Reddy; D. Srihari; K. R. Reddy and G. Neeraja. 2003. Integrated nutrient management in onion (*Allium cepa* L.). *Tropical Agric. Res.*, 15: 19.
- Jeyakumar, P., T. N. Balamoh an, N. Kumar and M. Kavino. 2007. Physiological basis of balanced fertilization for horticultural crops. In: N. Kumare (Ed). Training manual on role of balanced fertilization for horticultural crops. Horticultural college and Research Institute Tamil Nada Agricultural University. pp. 247-345.
- Jeyathilake, P.K.S., Reddy, I.P., Srihari, D. and Reddy, K. R. 2006. plus, Productivity and soil fertility status as influenced integrated use of N-fixing Biofertilizers, organic manures and inorganic fertilizers in onion. *Journal of Agricultural Sciences*, 2(1): 46-58.
- Jilani, M.S., A. Ghaffor, K. Waseem and J.I. Farooq. 2004. Effects of different levels of nitrogen on growth and yield of three onion varieties. *International Journal of Agriculture and Biology*, 3(6): 507-510.
- Jones, H.A. and Mann, L.K. 1963. Onions and other allies. Inter science Publishers, Inc. New York, United States of America.
- Kaiser, D.E., Mallarino, A.P. and Haq, M.U. 2009. Runoff phosphorus loss immediately after poultry manure application as influenced by the application rate and tillage. *Journal of Environmental Quality* 38: 299-308.
- Karim S.M.R. and N.R. Ibrahim. 2013. Effect of planting time, day length, soil pH and soil moisture on onion. *INT.J. Biol.Pharm.Allied, Sci.*, 2: 807-814.

- Katyal, J.R., 2000. Organic matter maintainance. Mainstay of soil quality. *J. Indian Soc. Soil Sic.*, 48: 633–872.
- Kebede Woldetsadik. 2003. Shallot (*Allium cepa* var. *ascalonicum*) responses to plant nutrient and soil moisture in a sub- humid tropical climate. *Journal of Horticultural sciences and Biotechnology*, 78(4):549-555.
- Kelleher, B.P., Leahy, J.J., Henihan, A.M., O'dwyer, T.F., Sutton, D. and Leahy, M.J. 2002. Advances in poultry litter disposal technology – a review. *Bioresource Technology* 83: 27-36.
- Ketter C.A.T., and W.M. Randle. 1998. Pungency assessment in onions. In S.J. Karcher (ed.). Tested Studies for Laboratory Teaching. *Association for Biology Laboratory Education*, 19: 177-196.
- Khan H., M. Iqbal, A. Ghaffoor and K. Waseem. 2002. Effect of various plants spacing and different nitrogen levels on the growth and yield of onion. *Journal Biological Science*, 2: 545–7.
- Khan MA, Abid M, Hussain N, Masood MU. 2005. Effect of phosphorus levels on growth and yield of maize (*Zea mays* L.) cultivars under saline conditions. *International Journal of Agriculture and Biology* 7:511–514.
- Kokeb Wolde Yohanes, Derbew Belew and Adugna Debela. 2013.Effects of Farm Yard Manure and Nitrogen Fertilizer Rates on Growth, Yield And Yield Components of Onion (*Allium Cepa* L.) at Jimma, South West Ethiopia.*Assian Journal of Plant Sciences* 12(6-8):228-234.
- Kumar, H., J.V. Singh, K. Ajay, S. Mahak, A. Kumar and M. Singh. 1998. Studies on the influence of nitrogen on growth and yield of onion. *Indian Journal of Agriculture Research*, 32(2): 88-92.
- Kumwenda, J.D.T., S.R. Waddingt, S.S. Snapp, R.B. Jones and Malcolm Blackie, 1995. Soil fertility management for the smallholder Maize-Based cropping system of southern Africa: A Review. Network research Working Paper Number 1. Soil fertility network for maize based cropping systems in countries of Southern Africa. CIMMYT. Maize programme. Zimbabwe: CIMMYT.
- Landon, J. R. 1991. Booker tropical soil manual: Hand book for soil survey and Agricultural land evaluation in tropics and sub tropics, Longman Inc., New York.
- Lee-Jongatae, Ha-Injong, Iee-Changung, Moon-Jinseong and Cho-Yongcho. 2003. Effect of N, P₂O₅ and K₂O application rates and top dressing time on growth and yield of onion (*Allium cepa* L.) under spring culture in low land. *Korean J. Hort. Sci. Tech.*, 21(4): 260-266.
- Lemma Desalegn and Shemelis Aklilu. 2003. Research Experiences in Onion production, Research Report No. 55, Ethiopia Agricultural Research Organization (EARO), Addis Ababa, Ethiopia. pp. 8, 128 & 152.

- Maier, N.A., A.P. Dahlenburg and T.K. Twigden. 1990. Effect of nitrogen on the yield and quality of irrigated onions (*Allium cepa* L.) cv. cream gold grown on siliceous sands. <http://www.publish.csiro.au/paper/EA9900845.htm>.
- Malik M. N. 2000. Horticulture. Biotech Books. Delhi. 586p.
- Mandal J., Ghosh, C. and Chattopadhyay, G.N. 2013. Proportional Substitution of Chemical Fertilizers with Vermi compost on Growth and Production Potential of Onion (*Allium cepa* L.) *Int. J. Bio-res.and Stress Mangt*, 4(2) special: 356-357.
- MARC (Melkassa Agricultural Research Center), 2004. Progress report for 1995–2003. EARO, Ethiopia.
- Maritus CHT, Vlelc PLG. 2001. The management of organic matter in tropical soils: what are the priorities? *Nutrients Cycling in Agro Ecosystems* 61:1–16.
- Marschner H. 1995. Mineral nutrition of higher plants. Second edition, Academic Press, London. Pp.:285-299.
- Mayer J, Pfeiffer EW, Beyer P. 2008. Biofortified crops to alleviate micronutrient malnutrition. *Current Opinion in Plant Biology* 11:166–170 DOI 10.1016/j.pbi.2008.01.007.
- Mcgrath, S., Maguire, R.O., Tacy, B.F. and Kike, J.H. 2009. Improving soil nutrition with poultry litter application in low input forage systems. *Agronomy Journal* 102: 48-54.
- Melaku Fisseha. 2010. Responses of onion (*Allium cepa* L.) to combined application of farmyard manure and inorganic nitrogen and phosphorous fertilizers at Alage. M.Sc thesis presented to Haramaya University, Ethiopia.
- Mengel, K., and E. A. Kirby. 2001. Principles of plant nutrient. *Klewer Academic publishers* (5th ed.). p.849.
- Metwally S. M. and E.A Abdel-Bary. 1999. Assessment of Application of Amendments to Sandy Soils Using Computer Model. *Zagazig J. Agric. Res.*2: 947-962.
- Millard, P., and B. Marshall, 1986. Growth, nitrogen uptake and partitioning within the potato crop (*Solanum tuberosum* L.) in relation to nitrogen application. *Journal of Agricultural Sciences. Cambridge*. 107: 421– 429.
- Miller, R.W., and R.L. Donanue, 1995. *Soils in Our Environment* (7th ed.). Prentice Hall, Englewood Cliff. pp 281.
- Mishra, B.B. and Nayak, K.C., 2004. Organic farming for sustainable agriculture. Orissa reviewed. 43p.
- MoARD, 2009. Rural Capacity Building project. Course for Training of trainers on improved *horticultural crop technologies*. pp. 5-19.

- Mondal, S.S., Debahrata Acharya, Arup Ghosh, and U. Thapa, 2004. Integrated management of organic and inorganic sources of nutrient to improve productivity and quality characters of rice and onion in rice onion cropping sequence. *Envir.And Ecology*, MKK publication, Calcutta, India:22: 125-128.
- Moray, M.G., Marey, R.A., Karam,S.S and Abo-Dahab, A.M.A. 2012. Productivity and storability of onion as influenced by the different levels of NPK fertilization. *Agricultural Research*, 38 (1): 171-187.
- Mozumder , S.N., M. Moniruzzaman and G. M. A. Halim. 2007. Effect of N, K and S on the yield and storability of transplanted onion (*Allium cepa* L.) in the hilly region. *Journal of Agricultural and Rural Development*, 5(1 and 2): 58-63.
- Mugwira, L.M., and H.K. Murwira, 1998. A review of research on cattle manure on soil fertility amendment in Zimbabwe: some properties. In Waddingt,S.T., H.K. Murwira, J.D.T. Kumwenda, D.Hikwa and F.Tagwira(Eds). pp. 195-202.
- Muhammad S. J. 2004. Studies on the management strategies for bulb and seed production of different cultivars of onions (*Allium cepa* L.). A dissertation submitted to Gomal University, Deraismil khan and Pakistan. 449p.
- Nasreen, M. M. Haque, M. A. Hossain and A. T. M. Farid. 2007. Nutrient Uptake and Yield of Onion as Influenced by Nitrogen and Sulphur Fertilization. *Bangladesh Journal Agricultural Research*, 32(3): 413-420.
- Ndayisaba PC. 2014. Effects of inorganic and organic fertilizers on nutrient uptake, soil chemical properties and crop performance in maize based cropping systems in Eastern Province of Rwanda. *Doctoral dissertation*.
- Neeraja, G., K.M. Reddy, I.P.Reddy and Y.N. Reddy. 1999. Effect of irrigation and nitrogen on growth, yield and yield attributes of rabi onion (*Allium cepa* L.) in Andhra Pradesh. *Vegetable Science*, 26(1): 64-68.
- Ojala , J., C. Stark, and G.E. Kleinkopf. 1990. Influencing of irrigation and nitrogen management on potato yield and quality. *American Plant Journal*, 67:29-43.
- Ojeniyi, S. O. 2000. Effect of goat manure on soil nutrients and okra yield in a rain forest area of Nigeria. *Applied Tropical Agric*.5:20-23.
- Oliveira C, Alves V, Marriel I, Gomes E, Scotti M, Carneiro N, Guimaraes C, Schaffert R, Sá N. 2009. Phosphate solubilizing microorganisms isolated from rhizosphere of maize cultivated in an oxisol of the Brazilian Cerrado Biome. *Soil Biology and Biochemistry* 41:1782–1787 DOI 10.1016/j.soilbio.2008.01.012.
- Olsen SR, Cole CV, Watanable FS, Dean LA (1954). Estimation of phosphorus in soils by extraction with sodium bicarbonate. USDA, circular 939:1-19.
- Olsen, S.R. & L.E. Sommer. 1982. Phosphorus. In:A.L. R.H, Miller and D.R. Keeneys (Ed). *Method of soil analysis chemical and biological properties*. Am. Soc. pp. 403-430.

- Ouda BA, Mahadeen AY. 2008. Effect of fertilizers on growth, yield, yield components, quality and certain nutrient contents in broccoli (*Brassica oleracea*). *Int. J. Agr. Biol.*, 10 (6): 627-632.
- Palm C.A., R.J.K Myers and S.M. Nandwa. 1997. Combined use of organic and inorganic nutrient source for soil fertility maintenance and replenishment. In: Buresh *et al* (eds.). Replenishing soil fertility in Africa. Special publication No. 51. Wisconsin, USA. Pp. 193-217
- Pathak, C.S., 1994. Allium improvement in the tropics: Problems and AVRDC Strategy. *Acta. Hort.* 358:23-29.
- Patricia, I. and S. K. Bansal. 1999. Potassium and integrated nutrient management in potato. A paper presented at the Global Conference on Potato. New Delhi, India.
- Power, J.F. and Dick, W.A. 2000. Land Application of Agricultural, Industrial, and Municipal By- products. Soil Science Society of America Inc., Madison, WI.
- Rabinowitch H.D. and J.L. Brewster. 1990. Onion and allied crops. Vol. I. Botany, physiology and genetics. CRS Press, USA.
- Rabinowitch, H.O. and Currah, L., 2002. Allium Crop Science: Recent Advances. CABI Publishing. U.K. 585p.
- Randle, W.M. and. Ketter, C.A. 1998. Pungency assessment in onions. Proceedings of the 19-work shop conference of the Association for Biology Laboratory Education.
- Reddy, K.C. and K.M. Reddy, 2005. Differential levels of vermin-compost and nitrogen on growth and yield in onion (*Allium cepa* L.) - radish (*Raphanus sativus* L.) cropping system. *Journal of Research Angraui*, 33(1): 11-17.
- Saha, D. 2013. Onion: Anticancer sulfur compounds with high cancer chemo prevention potential. *Science, Technology and Arts Research Journal*, 2(3): 01-02.
- Saleem R. 2010. Economic feasibility of integrated nutrient management for sustainable rainfed maize-legume based intercropping systems. Doctoral dissertation, University of Arid Agriculture, Rawalpindi.
- Sankar V., Veeraragavathatham, D. and Kannan, M. 2009. Studies on organic farming in onion (*Allium cepa* L.) for the production of export quality bulbs. *As. J. Hort.* 4: 65-69.
- Satyanarayana, V. and Prasad, P.V., 2002. Influence of integrated use of farmyard manure and inorganic fertilizers on yield and yield components of irrigated lowland rice. *J. Plant Nutrition*, 25(10): 2081–2090.
- Sekhon GS, Meelu OP. 1994. Organic matter management in relation to crop production in stressed rain fed systems. In: Virmani SM, Katyal JC, Esnaran H, and Abrol IP, editors. Stressed ecosystems and sustainable agriculture, Oxford University Press and IBH, New Delhi.

- Shaheen A, Fatma M, Rizk A, Singer SM. 2007. Growing Onion Plants without Chemical Fertilization. *Res. J. Agr. Biol. Sci.*, 3(2): 95-104.
- Shalini, S.B., H.T. Channal, N.S. Hebsur, P.R. Dharmatti and P.A. Sarangamath, 2002. Effect of integrated nitrogen management on nutrient uptake in knolkhol, yield and nutrient availability in the soil. *J. Karanataka Agri. Sci.*, 15 (1): 43-46.
- Shanmugasundaram S. and Kalb T. 2001. Suggested cultural practice for onion. AVRDC Training guide. Pp. 1-20. <http://www.avrdc.org>.
- Sharif M, Ahmad M, Sarir MS, Khattak RA. 2004. Effect of organic and inorganic fertilizers on the yield and yield components of maize. *Pakistan Journal of Agriculture, Agricultural Engineering Veterinary Sciences* 20(1):11–16.
- Sharma AR, Mitra BN. 1991. Effect of different rates of application of organic and nitrogen fertilizers in a rice-based cropping system. *The Journal of Agricultural Science* 117(03):313–318.
- Sharma R.P., Datt, N. and Sharma, P.K. 2003. Combined application of nitrogen, phosphorus, potassium and farmyard manure in onion (*Allium cepa L.*) under high hills, dry temperate conditions of north-western Himalayas. *Indian J. Agri. Sci.*, 73: 225–227.
- Sharpley, A., Meisinger, J.J., Breeuwsma, A., Sims, J.T., Daniel, T.C. and Schepers, J.S. 1998. Impact of animal manure management on ground and surface water quality, in: Hatfield, J.L. & Stewart, B.A. (Eds) *Animal Waste Utilisation: Effective Use of Manure as a Soil Resource*, pp.173-242 (Chelsea, MI, Ann Arbor Press).
- Sharpley, A.N., Herron, S. and Daniel T. 2007. Overcoming the challenges of phosphorus-based management challenges in poultry farming. *Journal of Soil and Water Conservation* 58: 30-38.
- Singh T, Singh SB, Singh BN. 1989. Effect of nitrogen, potassium and green manuring on growth and yield of rainy season onion (*Allium cepa L.*). *Narendra Deva J. Agric. Res.*4(1):57-60.
- Smith, D.L. and Hamel. C. 1999. Crop yield physiology and processing. Springer Germany. Soil water potentials as irrigation threshold. *Horticultural Science*, 33: 1188-1191.
- Synman HG, Jong DE, Aveling TAS. 1998. The stabilization of sewage sludge applied to agricultural land and the effects on maize seedlings. *Water Sci.Technol.* 38 (2): 87-95.
- Sorensen JN, Grevsen K. 2001. Sprouting in bulb onions (*Allium cepa L.*) as influenced by nitrogen and water stress. *Journal Horticultural Science and Biotechnology*, 76: 501-506.
- Suge JK, Omunyin ME, Omami EN. 2011. Effect of organic and inorganic sources of fertilizer on growth, yield and fruit quality of eggplant (*Solanum Melongena L.*). *Archives of Applied Science Research* 3(6):470–479.

- Sukprakarn S., S. Juntakool, R. Huang, and T. Kalb. 2005. Saving your own vegetable seeds—a guide for farmers. AVRDC publication number 05-647. AVRDC—the World Vegetable Center, Shanhua, Taiwan. 25 pp.
- Tadila Getaneh. 2011. Effect of manure and nitrogen rates on yield and yield components of garlic (*Allium sativum* L.) at Haramaya, Eastern Ethiopia. M.Sc thesis presented to Haramaya University, Ethiopia.
- Takele Gebrie, 2004. Modernizing Ethiopian Agriculture: the way towards food self sufficiency. In: M, Siyum and K, Ensermu (ed). *Proceeding of national work shop*. Addis Ababa.
- Tekalign Mamo & Asgelel Dibabe. 1994. Soil Microbiology Research. Cool Season Food Legumes of Ethiopia Proceedings of the first National Cool Season Food Legumes Review conference. 440pp.16-20 December, 1993. Addis Ababa, Ethiopia.
- Tisdale S.L., W. Nolson L., Beaton D. James and John L. Halvin. 1995. Soil Fertility and Fertilizers (5th ed.). Macmillan Publishing Company, New York. Pp. 52-96.
- Tukur, H.M, Hassan, W.A, Singh, A. and Yakubu, A.I. 2009. Organic Agriculture for Better Livelihoods. Proceedings of the Third National Conference on Organic Agriculture in Nigeria. Usmanu Danfodiyo University, Sokoto, Nigeria, 11th – 15th November 2007, pp. 120-196.
- Vachhani MU, Patel ZG. 1993. Growth and yield of onion (*Allium cepa* L.) as influenced by levels of nitrogen, phosphorus and potash under South Gujarat conditions. *Progressive Hort.* 25(3):166-167.
- Valenzuela, H., Shimabuku, R., Kratky, B. and Hamasaki, R., 1999. Bulb onion production in Hawaii. Published by CTAHR, Manoa Hawaii.
- Vanlauwe B, Diels J, Sanginga N, Merckx R. 2002. Integrated plant nutrient management in Sub-saharan Africa: *from concept to practice*. Oxon: CABI Publishing, 352.
- Walkley, A. & C.A. Black, 1934. An examination of different methods for determining soil organic matter and the proposed modification by the chromic acid titration method. *Soil Sci*: 37: 29-38.
- Wondimu, T. 2009. The effect of combination of farmyard manure and inorganic nitrogen on onion yield and soil fertility. An MSc Thesis Presented to the school of graduate studies of Mekelle University. 38p.
- Wondye mengistu 2017. Effects of different levels of farm yard manure and NPS fertilizer on yield and yield components of onion (*Allium cepa* L.) in the case of Koga, and Rib irrigation schemes, north western Ethiopia. M.Sc thesis presented to Bahir dar University, Ethiopia.

- Yadav R., D.H. Dwivedi, Govind and S. Maji. 2015. Effect of integrated nutrient management on growth and yield of onion (*Allium cepa* L.) cv. Pusa Madhvi. *Journal Crop and Weed*, 11(1):49-53.
- Yadav RL, Sen NL, Yadav BL. 2003. Response of onion to nitrogen and potassium fertilization under semi-arid condition. *Indian Journal of Horticulture*, 60(2): 176-178.
- Yemane Kahsay, Derbew Belew and Fetien Abay. 2014. Effect of intra-row spacing on plant growth and yield of onion varieties (*Allium cepa* L.) at Aksum, Northern Ethiopia. *African Journal of Plant Science*, 9(10): 931-940.
- Zang, W., Han, D. Y., Dick, W. A., Davis, K. R. and Hoitink, H. A. J. 1998. Compost and compost water extract induced systemic acquired resistance in Cucumber and *Arabidopsis*. *Phytopathology*, 88: 450 – 455.

7. APPENDICES

Appendix table 1. Mean square for growth and phenological parameters of (Bombay Red) onion grown at Alage

Sources of variation	DF	PH	LL	LN	DM
Replication	2	12.02**	0.33ns	0.69ns	7.00ns
Poultry manure	2	60.77***	76.74***	16.11***	45.80***
N rate	2	52.02***	26.73*	5.86*	50.58***
Poultry*N rate	6	5.58*	11.52ns	1.97ns	3.25ns
Error	22	1.90	4.88	1.33	3.30
CV (%)		2.60	4.43	10.12	1.62

*PH= plant height, LL= leaf length, LN= leaf number per plant, MD= maturity days, DF= degree of freedom * =Significant at ($P < 0.05$), **= Significant at ($P < 0.01$), ***= significant at ($P < 0.001$) and ns =Non-significant ($P > 0.05$).*

Appendix table 2. Mean square for yield and yield component parameters of (Bombay red) onion variety at Alage

Sources of variation	DF	BL	BD	ABW	TBIY	TBY	MBY	UBY	BDMC	HI
Replication	2	0.003ns	0.005ns	163.44ns	301.77ns	62.23ns	58.79ns	0.05ns	0.22ns	4.33ns
Poultry manure	2	1.63***	1.73***	126.92ns	143.48ns	199.74*	206.51*	0.10**	19.73***	214.9***
N rate	2	0.93**	1.21***	473.44**	229.52ns	130.27ns	141.85ns	0.25***	22.7***	204.3***
Poultry*N rate	6	0.03ns	0.28*	35.81ns	51.67ns	41.40ns	40.17ns	0.045ns	0.88ns	29.92*
Error	22	0.10	0.11	71.08	100.74	61.77	60.92	0.018	1.29	10.15
CV (%)		8.52	7.40	18.21	14.15	13.65	13.77	15.45	10.85	4.14

BL= bulb length, BD= bulb diameter, ABW= average bulb weight, TBIY= total biomass yield, TBY= total bulb yield, MBY= marketable bulb yield, UBY= unmarketable bulb yield, BDMC= bulb dry mater content, HI= harvesting index, DF= degree of freedom

Appedix table 3. Interaction effects of poultry manure and nitrogen level on onion (Bombay red) gown at Alage.

PM t/ha	N kg/ha	PH	LL	BD	BL	LN	DM	TBIY	ABW	TBY	MBY	UBY	BDMC	HI
0	0	47.33d	43.33	3.13e	3.03	9.00	105.00	61.66	34.66	49.33	48.07	1.26	10.00	70.33c
0	46	47.66d	46.10	4.00d	3.26	9.33	109.67	62.66	41.33	49.00	48.10	0.90	12.31	73.00c
0	92	53.00b	47.66	4.50bcd	3.53	10.66	111.67	73.00	46.66	62.00	61.03	0.96	13.23	72.00c
5	0	50.33c	49.81	4.20cd	3.60	10.00	110.67	68.33	44.00	51.66	50.50	1.16	9.91	71.00c
5	46	54.00ab	49.36	4.66abc	4.03	11.66	112.00	67.66	48.00	57.33	56.53	0.79	11.23	74.66c
5	92	54.00ab	52.00	4.70abc	4.00	11.33	112.67	73.00	48.00	53.00	52.36	0.63	13.47	75.00c
10	0	52.00bc	50.33	4.60abc	3.63	12.33	111.67	73.66	37.33	55.26	54.36	0.90	8.97	74.00c
10	46	56.00a	53.00	5.03ab	4.16	12.00	113.33	73.33	49.33	60.90	60.10	0.80	9.69	80.66b
10	92	56.00a	51.66	4.53bcd	4.23	12.66	115.33	74.33	58.00	62.23	61.43	0.80	10.86	86.66a
15	0	53.00b	52.33	4.60abc	3.90	11.00	111.67	64.66	42.66	60.33	59.46	0.86	7.27	73.33c
15	46	56.00a	48.46	4.93ab	4.56	14.00	113.67	76.00	49.33	64.00	63.10	0.89	9.26	85.00ab
15	92	56.00a	55.33	5.10a	4.40	12.66	115.67	82.33	56.00	65.66	64.99	0.67	9.56	86.33a
Significance		*	ns	*	ns	Ns	Ns	ns	ns	ns	Ns	ns	ns	*

Where, ns, *, = interaction is significant at $P > 0.05$ and $P < 0.05$, level of probability, respectively. PH=plant height, LL=leaf length, BD=bulb diameter, BL=bulb length, LN= leaf number, DM= days to maturity, ABW= average bulb weight, TBIY= total biomass yield, TBY= total bulb yield, MBY= marketable bulb yield, UBY= unmarketable bulb yield, BDMC= bulb dry mater content and HI= harvesting index

Appendix table 4. Linear correlation among phenology, growth variables, yield and yield components

par	PH	LL	BD	BL	LN	DM	TBIY	ABW	TBY	MBY	UBY	BDMC	HI
PH	1												
LL	0.70***	1											
BD	0.73***	0.61***	1										
BL	0.74***	0.56***	0.78***	1									
LN	0.63***	0.41**	0.60***	0.61***	1								
DM	0.83***	0.68***	0.69***	0.68***	0.56***	1							
TBIY	0.30ns	0.28ns	0.43***	0.52***	0.40*	0.29ns	1						
ABW	0.53***	0.41*	0.31ns	0.54***	0.43**	0.61***	0.42*	1					
TBY	0.46**	0.29ns	0.51**	0.46**	0.45**	0.32ns	0.56***	0.36*	1				
MBY	0.47**	0.30ns	0.53***	0.47**	0.46**	0.33*	0.57***	0.37*	0.99***	1			
UBY	-0.61***	-0.63***	-0.57***	-0.51**	-0.40*	-0.67***	-0.20ns	-0.38*	-0.06ns	-0.09ns	1		
BDMC	-0.79***	-0.63***	-0.71***	-0.67***	-0.53***	-0.72***	-0.33*	-0.50**	-0.48**	-0.49**	0.63***	1	
HI	0.67***	0.45**	0.56***	0.65***	0.64***	0.66***	0.23ns	0.45**	0.37*	0.39*	-0.46**	-0.68***	1

Where, ns, *, **, *** = correlation is significant at $P > 0.05$, $P < 0.05$, $P < 0.01$ and $P < 0.001$ level of probability,

respectively. PH=plant height, LL=leaf length, BD=bulb diameter, BL=bulb length, LN= leaf number, DM= days to maturity,

ABW= average bulb weight, TBIY= total biomass yield, TBY= total bulb yield, MBY= marketable bulb yield, UBY= unmarketable

bulb yield, BDMC= bulb dry mater content and HI= harvest index

Appedix table 5. Some physical and chemical properties of the experimental soils before planting of onion

Soil characteristics	Analytical value
pH	7.11
Available P(ppm)	22.66
Organic matter (%)	2.81
Organic carbon (%)	1.63
Total nitrogen (%)	0.14
C:N	11.64
Electric conductivity (ds/m)	1.94
Cation exchangeable capacity (cmol(+) kg ⁻¹ soil)	38.72
Particle size distribution (%)	
Sand	17
Clay	43
Silt	40
Textural class	Silty clay

Appedix table 6. Some chemical properties of poultry manure used in the experimental field

Chemical properties	Analytical value
Total N (%)	1.12
Total P (%)	1.2
Organic carbon (%)	13.00
Organic matter (%)	22.41
C:N	11.6

8. BIOGRAPHICAL SKETCH

The Author, Nejeha Redy, was born on September 14, 1991 in Eastern Harerge Gursum woreda, eastern Ethiopia from her father Mr. Redy Alemar and her mother Mrs. Medina Bushra. She attended primary school at fugnana birra elementary school and secondary education at Gursum senior secondary school. After completion of high school education in 2008, she joined Alage ATVET College in 2008 and graduated with a diploma in 2010 in plant science. Upon graduation, she was employed by Ministry of Agriculture and Natural resource to work Alage ATVET College as assistant instructor in plant science department. Then she joined Haramaya University in summer program in 2011 and graduated with Degree of Bachelor of Science (BSc.) in plant science in 2015. She joined the school of Graduate Studies at Hawassa University in 2016 to pursue a study leading to the Degree of Master of Science in Agronomy.