GROWTH AND BULB YIELD OF ONION (*Allium cepa Var. cepa*) VARIETIES IN RESPONSE TO NPSB FERTILIZER AT CHEHA DISTRICT, GURAGE ZONE

M.Sc. THESIS

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Growth and Bulb Yield of Onion (*Allium cepa Var. cepa*) Varieties in Response to NPSB Fertilizer at Cheha District, Gurage Zone

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We, the undersigned, members of the Board of Examiners of the final open defense by Teshome Denbu Bizuneh have read and evaluated his thesis entitled "Growth and Bulb Yield of Onion (*Allium cepa Var. cepa*) Varieties in Response to NPSB Fertilizer at Cheha District, Gurage Zone**"** and examined the candidate. This is, therefore, to certify that the thesis has been accepted in partial fulfillment of the requirements for the degree of Master of Science in Horticulture.

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BIOGRAPHICAL SKETCH

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ABBREVIATIONS AND ACRONYMS

ANOVA	Analysis of Variance
ATA	Agricultural Transformation Agency
CEC	Cation exchange capacity
CIMMYT	International Maize and Wheat Improvement Centre
CSA	Central Statistical Agency
CWAO	Cheha Wereda Agricultural office
DAP	Di-Ammonium Phosphate
DNA	Di-ribonucleic Acid
EARO	Ethiopian Agricultural Research Organization
EIAR	Ethiopian Institute of Agricultural Research
Ethio-SIS	Ethiopian Soil Information System
FAO	Food and Agricultural Organization of the United Nations
FAOSTAT	Food and Agricultural Organization Statistics
KCO	Potassium Di-Chromate
LSD	Least Significant Difference
masl	Meters above sea level
MoARD	Ministry of Agriculture and Rural Development
NPSB	Nitrogen, Phosphorus, Sulfur and Boron
PH	Power of Hydrogen
RCBD	Randomized Complete Block Design
SAS	Statistical Analysis Software
SNNPRS	South Nation Nationality People of Regional State

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ABSTRACT

Onion (Allium cepa L.) is one of the most important vegetable crops commercially grown in the world. It is a high value and income generating vegetable crops for most small scale farmers and commercial growers in Ethiopia. However, the productivity of onion is low at national as well as regional levels; due to various limiting factors such as lack of improved varieties and low soil fertility. Accordingly, a field experiment was conducted to evaluate growth and yield response of onion varieties to NPSB fertilizer rates at Cheha district, Guraghe zone during 2022 cropping season. The experiment was consisted of four onion varieties (Bombay Red, Nafid, Nafis and Nasik Red) and four levels of NPSB fertilizer (0, 195, 244 and 293 kg ha^{-1}) combined factoriallly and laid out in Randomized Complete Block Design with three replications. Yield and yield related parameters were recorded and subjected to analysis of variance. The analysis of variance for agronomic parameters showed that the main effects; variety and application of NPSB blended fertilizer rate were significant for almost all traits. Similarly all yield and yield related traits were significantly influenced by the interaction of varieties and NPSB fertilizer rate except plant height. The highest values for most of the response variables were recorded from variety Nafis combined with NPSB at rate of 293 kg ha^{-1}.The partial budget analysis revealed that the highest net benefit 414255(ETB ha^{-1}) with acceptable MRR was obtained from the variety Nafis combined with application of 244 kg ha^{-1} of NPSB fertilizer. Hence, the use of Nafis onion variety and application of 244 kgha^{-1} NPSB fertilizer rate was economically feasible and can be recommended for optimum production of onion in the study area and other areas having similar agro-ecology. However, as the experiment was done for only one season and single location, it has to be repeated over seasons and locations to have conclusive recommendation.

Key words: *Variety, blended fertilizer, bulb yield, Partial budget, MRR*

1. INTRODUCTION

Onion *(Allium cepa L.)* belongs to the genus Allium of the family Alliaceae which is believed to be originated in southwestern Asia, being the centre of diversification and variability, from where it was spread first across the world (Brewster, 2008). The introduction of the crop to the world historically associated with Romans and Greeks, which thought to be they have taken it into northern Europe, and ever since, it was widely cultivated throughout Europe during the Middle Ages. During his journey, Columbus was also taken onion from Europe to Caribbean countries and USA .The introduction to Africa in general and in Ethiopia, in particular, was not well known. However, it has suggested that as introduced by foreigners recently and by now produced widely in many parts of the country than the traditionally grown shallot (Adgo, 2008).

The onion is recognized as one of the most important vegetable crops that cultivated throughout the world since its introduction to the world. It has grown mainly as a food source and used as cuisine and value addition for different dishes. In Ethiopia, the consumption of this crop is very important in the food seasoning and in daily stews as well as in different vegetable food preparation .The chemical flavonoids, anthocyanin, fructo-oligosaccharides and organo-suphur compounds found in the onion is considered as medicinal and health benefits to fight different diseases including cancer, heart and diabetic diseases (Goldman, 2011).Due to this considerable benefits, the onion production is become increasing in different agro-ecologies of the country in small-scale production systems being as one component of commercialization for rural and urban peoples as sources of daily income and also job opportunity.

In Ethiopia, onion is produced by smallholder farmers and commercial growers for both local and export markets (Aklilu, 1994).It ranked second next to tomato, in production of all vegetable crops, which is mainly concentrated in central rift valley of the country particularly in the upper Awash and Lake Ziway areas (Bossie *et al.*, 2009). Despite to its recent introduction to the country, relatively, onion currently becomes a popular crop because of its yield potential per unit areas, the ease of propagation method, both by seed and bulb, and the presence of high domestic and export markets (Asfaw and Eshetu, 2015). Nikus and Mulugeta (2010), also mentioned the increasing rate area under onion production from time to time, mainly due to the merit of production and ease of marketing purposes. The crop can be cultivated twice per year both under the irrigation and rain feed conditions in different parts of the country (Belay *et al.*, 2015).However, the productivity of the crop in the country is far below (10.02tha^{-1}) as compared to the world average (19.7tha^{-1}) (FAO, 2012).

For being onion shallow and unbranched root system, it is weak in extracting nutrients, especially the immobile types. For these reason, it requires and often respond well to the addition of fertilizers (Rizk *et al*., 2012). In addition to that, to increase the productivity of onion, availability of high yielding varieties that are adapted to the specific growing area is crucial (Tesfalgn and Mohammed, 2015).

The well-known onion varieties grown in Ethiopia are Adama Red, Melkam, Red Creole, Bombay Red, Dereselign, Nafis, Nasik Red and Neptune for different agro-ecologies of Ethiopia based on their different characters (Beshir and Nishikawa, 2012). Among which Bombay Red and Adama Red varieties are widely grown in the country. However, the other varieties are not distributed to most growing areas of the country.

Onion is one of the most important vegetable crops cultivated in Gurage Zone both for household consumption and income generation. It is largely grown under supplementary irrigation condition during dry season. The area under onion production in Gurage Zone is in an increasing rate through time mainly due to the potential of production and ease of marketing. In 2013/2014 production season, a total of 9585 ha of land was covered by onion. The top producing districts of the zone include Abeshiege, Mareko, South Sodo, Sodo, East Meskan, Meskan and Cheha (DGZA, 2021).

Cheha district is one of the high potential areas for production of onion endowed with 4 permanent rivers and ample command areas. In 2021 production year 450 ha of land was covered with onion and a total 856 farmers were participated (CWAO, 2021). However, onion productivity in the district is very low (8.8t ha^{-1}) as compared to the national average (9.3 t ha^{-1}) and zonal average (9.5 t ha^{-1}) (CSA, 2017), perhaps because of shortage of seeds of improved varieties, poor agronomic practices including use of inadequate rate of fertilizer and disease and insect pest problems. Although there are a number of reports on Nitrogen and Phosphorus containing fertilizers requirements of onion, limited information are available on other sources of fertilizers that contain S and B. According to EIAR (2007), the blanket recommendation of fertilizers; 150 kg ha^{-1} of urea and 200kg ha^{-1} of DAP (105kg N ha^{-1} and 92kg P_2O_5 ha^{-1}) had been used for the production of onion in Ethiopia. After studying and mapping Ethiopian soils, the inclusion of nutrients likes S and B is under practice. Accordingly, blanket recommendation of N: P_2O_5: S: B (18.9N: 37.7P_2O_5:6.95 S: 0.1B) fertilizer is currently in use throughout onion growing area of Ethiopia (EthioSIS, 2014).

In a study conducted at Guba Lafto district from September 2017 to March 2018 under irrigation conditions, the growth and productivity of onion was improved by combined application of 325.36 kg ha^{-1}NPSB blended fertilizer (Molla *et al*., 2020).Fikre *et al.* (2021), reported that the most economically attractive combinations for small-scale farmers with low cost of production and higher benefits were the application of 125 $kgha^{-1}$ blended NPSB fertilizer in combination with Nafis onion variety. Similarly, Mebrahtom *et al*.(2020),conducted research on evaluation of blended fertilizer on growth performance and yield of onion under irrigated conditions, and reported that the highest total yield was obtained from Bombay Red onion variety that received 250 $kgha^{-1}$ NPSB.

As far as the study area is concerned, there is no study carried out in regard to response of onion varieties to the application rate of the newly introduced NPSB fertilizer. Research-based recommendations of onion varieties and the rate of NPSB fertilizer can increase onion crop production and increase the benefits of farmers. Therefore, it is imperative to identify the best onion verities and NPSB blended fertilizer rates for optimum onion production in the area.

1.1. Objectives

1.1.1. General Objective

To evaluate yield response of onion varieties to NPSB fertilizer rates, and economic feasibility at Cheha district, Guraghe zone

1.1.2. Specific objectives

- To evaluate growth and bulb yield of onion varieties at different rates of NPSB fertilizer

- To investigate the economic feasibility of treatment combination for optimum yield of onion

2. LITERATURE REVIEW

2.1. Origin and Description of Onion

Onion (*Allium cepa L.*) belongs to the family Alliaceae and the genus Allium (Hanelt, 1990).The genus contains about 750 species, among which onion, Japanese bunching onion, leeks and garlic are the most important once (Robinowith and Currah, 2002). The primary center of origin of onion is Central Asia with secondary center in Middle East and Mediterranean Region (Zohary and Hopf, 2000, Grubben and Denton, 2004).

Onion is herbaceous biennial monocot but cultivated as an annual crop for bulb production. For seed production onion is cultivated as biennial crop, in the first season bulbs are formed while flower stalks and seeds are developed in the second season (Lemma, 1998).

The onion bulb consists of the thickened bases of leaves attached to a small conical stem. The bulb varies from flat to round in shape. Leaves are long, round and hollow. Flowers are small in size and formed at terminal tip of the stems as umbels (Norman, 1992).

Onion bulbs are truncate formed from thickened leaf bases, thin and fibrous outer layers, inner layers without blades, up to 10 centimeter in diameter. Leaves are alternate, produced from a flattened conical basal stem, cylindrical, glaucous, becoming hollow. Flowers are borne on a scale, 30- 100 centimeter in height, protected by a spathe; terminal umbels produce numerous cymes, each with 5-10 flowers; perianth segments 6, petalloid, green-white, ovate, up to 5mm in length; stamens 6, alternating with perianth segments; ovary superior 3-locular, 2-ovules; style simple, becoming receptive after anther dehiscence. Seeds are smooth, black, wrinkled when dry; embryo curved, germinate epigeal. Fruits capsule in shape and splitting longitudinal (Tindall, 1983).

2.2. Distribution and Importance of Onion

Onion is grown in more than 170 countries in the world. In the 2016/2017 production year; the total area of 4,955,432 ha land was under onion production in the world, with a total of 93,168,548 tons and an average yield of 18.8 t ha^{-1} (Food and Agriculture

Organization Statistics of the United Nations,2017)(FAOSTAT,2017). According to this report, China and India are the world's largest producers of onion, followed by the USA, Pakistan, Turkey, and Iran.

According to statistical data from Central Statistical Agency (CSA) (2014), the production and productivity of onion in Ethiopia is estimated to be about 230,745.2 tons and 10.1 tha^{-1} respectively .Similarly, in 2016/2017 production season, the total area of 33,603.39 ha, with a total production of 327,475.2 tons with productivity of 9.75 t ha^{-1} was under onion production (CSA, 2017). In order to increase their income and improve their livelihood, small scale farmers produced Onion as one of the most important cash crops (Lemma and Shimelis, 2003). Currently the production of onion is increasing because of the expansion of irrigable areas in the country (MoARD, 2005).

Onion is by far the most important of all bulb crops cultivated commercially in most parts of the world (Simon, 1992).It is primarily used as flavoring agent in preparing various dishes. Its distinct pungency is due to the presence of a volatile oil (allyl propyl disulphide) (Malik, 1994). The matured bulb contains some starch, appreciable quantities of sugars, some protein, and vitamins A, B, and C and minerals (Malik, 2000). Moreover, the more pungent varieties of onion appear to possess the greatest concentration of health promoting phytochemicals. The National Cancer Institute has reported that onions contain antioxidants that help to block cancer and appear to lower Cholesterol. Onion contains carbohydrates (11.0 g), proteins (1.2 g), fiber (0.6 g), moisture 86.8 g), and several vitamin like vitamin A (0.012 mg), vitamin C (11 mg), thiamin (0.08 mg), riboflavin (0.01mg) and niacin (0.2 mg) and also some minerals like P (39 mg), Ca (27 mg), Na (1.0 mg), Fe (0.7 mg) and K (157 mg) per 100 g (Rahman *et al*., 2013).

2.3. Agro Ecology Requirement of Onion

Onion is adapted to a wide range of temperatures and relatively frost tolerant. Best production is obtained when cool temperatures prevail over an extended period of time that permit considerable foliage and root development before bulbing starts. Bulb formation is favored by relatively high temperatures (Raemaekers, 2001). An optimum temperature for the production of onion ranges from 18 to 27°C. Temperatures below the optimum ranges caused bolting of plants consequently reduced bulb yield. Similarly temperatures above 30°C lead to early maturity of the plant and reduced bulb yield (Lemma, 1998).

Onion has specific temperature requirements for seed and bulb production. In Ethiopia, day temperatures ranging from 20 0C – 26 0C and night temperatures of 11 – 15 0C are ideal for bulb production, whereas temperatures between 9 0C and 17 0C are favorable for onion seed production because these temperatures induce flower stalk development in onion (Lemma, 1998). Onion grows well in altitude between 700 to18000 meters above sea level (Lemma, 2004).Onion can be grown in all types of soils. But for higher yield well drained friable sandy loam soils with high fertility and plenty of organic matter are preferred (Brewster, 1994). Onion is also sensitive to highly acid soils and grows best when the pH is between 6.2 and 6.8 (Raemaekers, 2001).

According to (Birhanu, 2016), if irrigation is available, are preferred and often used. Adequate moisture is critical for uniform seedling emergence. Because of the shallow rooting system of the crop, Soils with high water holding capacity are better able to provide moisture. But must also drain well to be suitable .when available soil moisture is low, Growth is retarded but onions are also sensitive to a high water table or water logging. Uniform moisture availability about 400-800mm per crop is conducive to large bulb size and high yields. Favorable soil pH is about 6.5 – 8.0 in mineral soils and about 5.8 in peat soils.

Generally, onion grows between 500-2400 masl; the best growing altitude so far known in Ethiopia is between 700-1800 masl. Besides altitude which has an indirect bearing on climate, onion production is affected by temperature, rainfall and soil condition. It is grown under mild seasons without extremes of heat, cold or moderate rainfall. Optimum day and night temperatures of 18.3-23.90 and 10-12°C respectively are ideal for onion bulb production. But lower temperature is preferred for seed stalk development. Onion requires deep alluvial and friable or sandy loam soil with a pH of 5-6.8. Onion does not tolerate badly drained soil and also it is moderately sensitive to soil salinity (WARC, 2012).

2.4. Onion production status

The production of vegetables is becoming important with the expanding irrigated agriculture and with the growing awareness on the importance of the sector as source of income, improved food security, sources of raw materials for industries, employment opportunity because it demands large labor force. The expansion of water harvest schemes in small farmers sector and irrigated agricultural development projects have made significant contribution to the development of the sector. The success of production depends on the adoption of improved technologies such as cultivars that have acceptable standard and high value in the local use and export markets (Lemma *et al*., 2006).

Because of its wide benefits in our daily foods requirements, the production of onion crop is worldwide. It is largely produced in the developed nations and has dominated in the international markets due to its higher quality production and longer storage life (Opara, 2003). China is the top producer of the world followed by India and USA (Manna, 2014). According to FAO STAT (2012), the world total onion production is 742.51 million tons per annum out of this China shared 205.08 million tons, India 133.72 million tons, and the USA 33.21 million tons respectively. In Africa, Egypt is the leading country by producing 22.08 million tons of onion per year for domestic and international markets that rank as the fourth of world producer (Kulkarni *et al*., 2014).

Onion is a high-value bulb crop that has produced by smallholder farmers and commercial growers for both local and export markets in Ethiopia (Aklilu, 1994). It ranked the second in production of all vegetable crops next to Tomato, which has been concentrated in the central rift valley of the country particularly in the upper Awash and Lake Ziway areas (Bossie *et al*., 2009). Onion is currently becoming a popular crop relatively despite to its recent introduction to the country because of its yield potential per unit areas, the ease of propagation method both by seed and bulb method, and the presence of high domestic and export markets (Asfaw and Eshetu, 2015). However, the production and productivity of the crop are far below (10.02tha^{-1}) the world average (19.7 tha^{-1}) despite to its year-round production scenarios (FAO, 2012).

This low yield results indicate that the presence of a huge gap in production and productivity at the country because of the absence of improved cultivars, application of inappropriate agronomic practices and limited attention/awareness on the benefits of intensive production.

2.5. Production Constraints of onion in Ethiopia

There are a number of production problems that make the production of onion difficult. Among these low bulb yield because of non-optimal agronomic practices, unavailability and high cost of seed, prevalence of diseases and insect pests, poor soil fertility, inappropriate rate of fertilizer application, unavailability of quality seeds, lack of improved varieties and production technologies are basic problems associated with onion (Misgana and Awoke, 2017; Lemma and Shimelis, 2003; Demisie and Tolessa, 2018). Successful onion production depends on the selection of varieties that are adapted to different conditions imposed by specific environment (Brewester,1994).Similarly, as reported by Yemane *et al. (*2016), small scale farmers accustomed to limited use of improved seeds and fertilizers .The optimum level of any agronomic practice such as fertilizer requirement vary with growing environment and variety.

According to Nikus and Mulugeta (2010), the low productivity could be attributed to the limited availability of quality seeds and associated production technologies used are among the others. In addition to this, most of the time onion is produced by smallholder farmers, appropriate agronomic practices employed agricultural inputs such as fertilizers, improved varieties and pesticides are not sufficiently used, and inappropriate postharvest handling practices are done. It is very difficult to give a general recommendation for agronomic management that can be applicable to different varieties and agro-ecological zones.

2.6. Importance of Blended Fertilizer for Crop Production

Fertilizer blending is defined as the mechanical mixing of two or more granular fertilizer materials to produce mixtures containing nitrogen (N), phosphorus (P), sulfur (S) and other essential plant nutrients (Beaton, 1997). The basis to produce more crop output from existing land under cultivation is proper use of balanced fertilizers (Caruso *et al*., 2019).

Knowing plant nutrients requirement of a given area has vital role in enhancing crop production and productivity on sustainable basis. Nevertheless, increasing crop yields through the use of N and P alone can deplete other nutrients (FAO, 2000). Fertilizers are efficient exogenous source of plant nutrients (Akram *et al.*, 2007), since plant growth and crop production require adequate and balanced supply of nutrients in order to maximize productivity by optimizing the plant nutrient uptake. Several studies reported that chemical fertilizers are the major nutrient sources to improve crop productivity (Akram *et al.*, 2007).

Generally blended fertilizer allows small batches of high analysis soil and crop specific fertilizers to be mixed and transported in an economical manner contributing additional profit for farmers and improving the environment because it provides balanced fertilization (Mekashaw *et al*., 2020).

2.7. Response of Onion to Inorganic Fertilizers

2.7.1. Response of onion to nitrogen

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 electrical discharge. Similarly, mineralization of organic nitrogen to inorganic forms depends on temperature, level of soil moisture and supply of oxygen (Tisdale *et al.*, 1990; Miller and Donanue, 1995).

Nitrogen is a central part of the essential photosynthetic molecule and chlorophyll and also it is an important component of proteins, enzymes, and vitamins in plants. (Marschner, 1995).Therefore, nitrogen is required by plants in much greater quantities than most of the nutrients and essential to increase onion yield both in quantity and quality (Kafkafi and Genbaum, 1971).

Onion is a heavy feeder of nutrients and require ample amount of nitrogen for optimum yield. Too much nitrogen can result an excessive vegetative growth and thus delay maturity. In addition to these, excessive vegetative growth increases susceptibility of onion plants to diseases and reduces dry matter contents and storability of onion bulbs. Consequently excess nitrogen results reduced onion yield both in quantity and quality (Sorensen and Grevsen, 2001). On the other hand, under sub-optimal supply of nitrogen, onion plants can be severely stunted resulting undersized bulbs and thus reduced yield. Hence, sub-optimal levels of this nutrient in the soil adversely affect the quantity, quality, and storability of onion bulbs. In such conditions application of optimum amount of nitrogen fertilizers is especially important to produce optimum-sized onion bulbs (Rice *et al*., 1993). Uptake levels of nutrients by onion crops may vary from less than 50 kg to more than 300 kg N ha^{-1}, depending on cultivar, climate, plant density, fertilization and yield levels (Salo, 1999).

Soleymani and Shahrajabian (2012) showed that the highest and the lowest marketable yield were obtained in to the application of 300 kg N ha^{-1} and 0 kg N ha^{-1}, respectively. Negash *et al*. (2009) also reported that increasing the rate of N fertilization from 0 to 138 kg ha^{-1} increased total bulb yield from 19.26 t ha^{-1} to 32.24 t ha^{-1}.Similarly, increasing the rate of nitrogen application from 0 to 138 kg ha^{-1} significantly increased marketable bulb yield from 18.82 t ha^{-1} to 31.90 t ha^{-1} which was 69.5% higher than the control. Jilani (2004) reported that with increase in dose of nitrogen up to120 kg N ha^{-1} the marketable and total bulb yield was increased, but below this level the total yield t ha^{-1} began to decrease.

2.7.2. Response of onion to phosphorous

Phosphorus is known to be the second most important plant growth limiting nutrient (Tisdale *et al.*, 1990). It makes about 0.2-0.5% of the plant's dry weight (Bieleski, 1973). Phosphorus is involved in several physiological and biochemical processes of plants and also it is components of membranes, chloroplasts and mitochondria and constituent of sugar. For these reason Phosphorus played a crucial role in energy transfer reactions and metabolic processes in plant maturity, fruit setting, and seed production (Brady and Weil, 2002).

Phosphorus deficiency is one of the largest constraints to crop production in many tropical soils. The reason is either low content of phosphorus in the soil or high phosphorous fixation (Fairhurst *et al*., 1999). Therefore, most of the soils throughout the world are phosphorus deficient (Batjes, 1997; Zaidi and Mohammad, 2005).

Phosphorus is a major building block of DNA molecules; hence, the presence of phosphorus in the soil encourages plant growth (Pant and Reddy, 2003). In addition (Hinsinger, 2001) reported that the two forms of phosphorus in soil are organic and inorganic. Therefore, inorganic phosphorus is readily absorbed and used by plant if it is not fixed.

Phosphorus fertilizer had a major effect on yield of onion plant, hence increased total bulb yield and its components .It may be attributed to the enhancement of phosphorus on the plant growth and it's reflected on the bulbs yield. Many investigators had obtained a similar trend of results and all of them agreed that the presence of phosphorus in the soil encourages plant growth, because phosphorus is an essential nutrient (Gupta and Sharma, 2000, Shafeek *et al.*, 2004).Phosphorus deficiencies in onions reduce root and leaf growth, bulb size, and yield and can also delay maturation (Greenwood et al., 2001).

According to Amin *et al.* (2007), fertilizer application significantly increased the bulb yield of onion in all nutrient elements over the control. According to Shaheen *et al.* (2007), application of 92 kg ha^{-1} phosphorus fertilizer increased total bulb yield. More over application of 69 kg N ha^{-1}and 40 kg ha^{-1} of P enhanced the growth of onion plant and resulted in optimum fresh total and marketable bulb yield (Abdissa and Pant, 2011);

Uzma *et al*. (2016), reported that a low level of phosphorus fertilizer application results in a reduction in leaf expansion and leaf surface area, as well as the number of leaves in garlic.

2.7.3. Response of onion to sulfur

Sulfur is also an essential plant nutrient required for growth and development According to Melaku (2019), Sulfur plays important roles in the growth and development of plants. Sulfur is an important component of two amino acids, cysteine and methionine, which are essential for protein formation; necessary for the formation of vitamins and synthesis of some hormones and glutathione; involves in redox reactions; improves tolerance to heavy metal toxicity; components of sulfo-lipids. It serves to enhance water solubility of organic compounds, which may be important in dealing with salinity stress. Sulfur deficiency symptoms are similar to those of nitrogen. However, N deficiency symptoms first appear in the older leaves; generally while sulfur deficiency symptoms first appear in the younger leaves because S is not easily translocated in the plant. Sulfur-deficient plants lack vigor, are stunted, are pale green to yellow in color, and have elongated thin stems.

For being macronutrient, it has a positive effect on quality of onion (Bloem *et al.,* 2004). It is important in the expression of the flavor intensity of bulbs which is associated with pungency and sugars contents of onion. Onion is a sulfur loving plant and is required much for proper growth and increased yield of onion (Bloem *et al.,* 2004). The volatile sulfur compounds in onion are released when onion bulbs are cut or bruised through the action of the enzyme allinase. The amount and kinds of sulfur compounds present in the bulb differ with onion varieties. Moreover sulfur is essential for building up sulfur containing amino acids (Anwar *et al*., 2001).

Application of sulfur to the soil has several effects such as reducing pH, improving soil-water relation and increasing availability of nutrients like P, Fe, Mn and Zn (Marschner, 1998). Sulfur requirements of onion vary with soil texture, leaching losses, sulfur content of irrigation water, previously used fertilizer and amendments containing sulfur (Ahmed *et al*., 1988). They reported that the diameter and weight of onion bulbs were significantly improved with the application of sulfur up to 24 kg $ha^{-1}$and non-application of sulfur in deficient soils resulted low yield of onion. Ayyub *et al. (*2013) reported that application of 40 kg S ha^{-1} resulted in the highest yield (10.65 t ha^{-1}) among the different doses of sulfur was recommended for better growth and yield of onion under silt loam in texture having pH around 6.5.

2.7.4. Response of onion to boron

Boron is essential for normal growth and production of sound and healthy vegetables. It is one of the important micronutrient for onion production and is essential for cell division, nitrogen and carbohydrate metabolism, protein formation and water relation in plant growth (Brady, 1990). Although it is quickly taken up from the soil, it is relatively immobile in the plant. It is important to maintain the correct balance of calcium, nitrogen and boron in the soil. High calcium and high nitrogen levels can reduce boron uptake.

Boron is relatively immobile in plant and its availability is essential at all growth stages, particularly during fruit and seed development. Boron has also help to reduce disease severity in some crops because of it effect that B has on plant metabolism, cell membranes and cell wall structure (Dordas, 2009).. Boron deficiency has been observed in soils with high organic matter contents (Valk *and* Bruin, 1989).Application of Boron increases bulb size, weight per bulb and yield of onion (Smriti *et al.*, 2002). Accordingly, Manna et al., (2014) reported that foliar application of boron with zinc significantly increases the marketable and total yield of onion. Similarly, Tariq *et al.*(2018) indicated the highest values for polar diameter, equatorial diameter, average bulb weight and total bulb yield was obtained when boron were applied at the rate of 1.500 kg $ha^{-1.}$

2.8. Response of Onion Varieties to fertilizer (NPSB) application

The notion of balanced fertilization lays the path for optimal plant nutrient supply so that crop yields can be realized to their full potential. Continuous application of unbalanced fertilizers, on the other hand, leads to a loss of soil fertility and a decrease in yield and also Crop cultivars perform differently under different agro-climatic conditions and various cultivars of the same species grown even in the same environment give different yields as the performance of a cultivar mainly depends on the interaction of genetic makeup and environment (Jilani &Ghafoor, 2003). According to Aklilu (1994), using the improved cultivars increases the productivity of onion bulbs beside to using recommended amount of fertilizer. Similarly, Assefa *et al.* (2015) finding, using the optimum amount of fertilizer nutrients substantially increases the productivity of onion bulbs beside to using of improved cultivars.

Because of Onion is one of the heavy feeders vegetable crop, it requires more mineral fertilizers than other vegetables for a bulb and shoot growth. According to Simon *et al.* (2015) report, three onion varieties (Adama Red, Bombe Red, and Nafis) have been tested at HumboWolaita zone was responded to different application of nitrogen and phosphorous fertilizer rates. The finding revealed that the size and onion bulb yield has increased as the level of nitrogen and phosphorous were increased which implies as the optimum nutrient management has a positive contribution to yield improvement of onion production and productivity especially for those areas where a nutrient deficiency is critical. Similarly, Field experiment was conducted to determine the effect of blended (NPSB) fertilizer rates on growth and yield of onion varieties. The results revealed that increasing the rate of NPSB blended fertilizer from 0 to 325.36 kg ha^{-1} increased the total bulb yield of onion significantly and linearly. This may be due to the increase in bulb size and bulb weight in response to nitrogen application that might have increased photosynthesis, and in turn, enhanced growth and expansion of vegetative growth as a whole (Molla *et al*., 2020).

3. MATERIALS AND METHODS

3.1. Description of the Study Area

The experiment was conducted on farmer's field in YefekTerek Wedro Kebele, Cheha District, Gurage Zone, in the 2022 production season. The site is located 177 km from Addis Ababa and 22 km from Wolkite, the capital of Gurage Zone. The geographical coordinates of the site is 8° 10'31"N latitude and 37° 52' 15.979"E longitude at an altitude of 1954meters above sea level (EIAR, 2011; SNNPRS, 1996, Mohammed *et al.* 2016; Bereket *et al*, 2018.Average annual minimum and maximum temperature ranges from 10.69 to 24.97°C respectively. The annual average rainfall is 1268 mm. Soil type of the experimental area is clay loam. Major crops grown are includes, *teff*, wheat and maize during the main cropping season whereas; tomato, onion, cabbage, potato and hot pepper are using irrigation and supplementary irrigation.

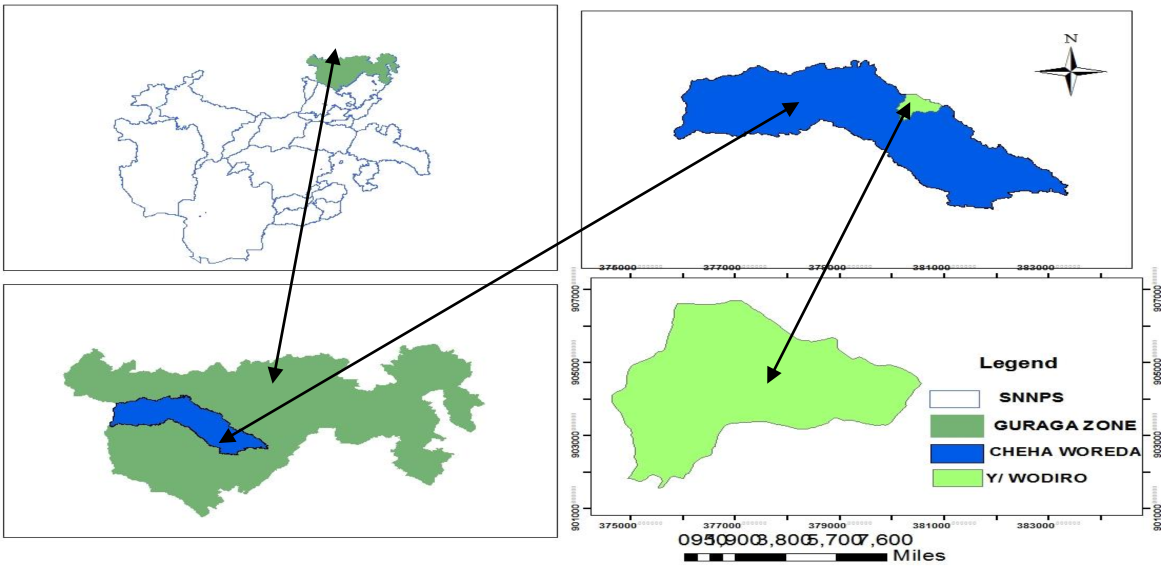

Figure 1 Location map of experimental area

3.2. Description of Experimental Materials

3.2.1. Plant materials

Four nationally released onion varieties namely Bombay Red, Nafid, Nafis and Nasik Red were used as planting materials for the experiment. All they were released by Melkasa Agricultural Research Center. Details about the onion variety presented in the Table 1.

.Table 1.Descriptions of Onion varieties used for the study

Variety (cultivar)	Year of release	Breeder (Maintainer)	Altitude (m asl)	Days to maturity	Yield (qt/ha)	Growth Habit
Bombay Red	1980	Melkasa research center	700-2000	<120	300	Medium
Nafid	2019	Melkasa research center	500-1800	99	422	Moderately Erect
Nafis	2010	Melkasa research center	500-1900	90-100	400	Erect
Nasik red	2004	Melkasa research center	500-1900	90-100	300	Erect

Source: Ministry of Agriculture variety release and registration (2011- 2019) and Melkasa Research Center

3.2.2. Fertilizer materials

Bended NPSB fertilizer (18.9N%, 37.7 P_2O_5%, 6.95S% and 0.1B %) and Urea (46% N) were used as the sources of fertilizer.

3.3. Treatments, Experimental Design and Lay out

The experiment was comprised of two factors; 4 varieties (Bombay Red, Nafid, Nafis and Nasik Red) and 4 rates of NPSB fertilizers (0,195,244 and 293 kg ha^{-1}). The blanket of 150 kg ha^{-1} of urea and 200 kg $ha^{-1}$of DAP fertilizers recommended for the production of onion in Ethiopia (EIAR, 2007). Recently, ATA (2016) recommended the use of blended NPSB fertilizer with 18.9% N, 37.7% P_2O_5, 6.95% S, 0.1% B instead of DAP. To furnish the EIAR (2007) recommended 200 kg DAP ha^{-1}, ATA (2016) has recommended the NPSB rate of 244kg ha^{-1} for onion production. In this experiment the recommended 244 kg ha^{-1}NPSB fertilizer was used as a base line fertilizer rate. Twenty percent above and below the baseline (293kg $ha^{-1}$and 195kg ha^{-1} respectively) were the other two NPSB fertilizer rates used, while '0'fertilizer was used as a control. The blanket recommendation of urea for onion production was taken. Therefore, there were 4x4 =16 treatment combinations.

The experiment was laid out in a Randomized Complete Block Design (RCBD) in factorial arrangement, with three replications, which resulted in a total of 48 experimental units (plots).The size of each plot was 3.4m × 1.8m=6.12m^2.The onion seedlings were planted in each plot with double row system. Planting spaces were 20cm between rows, 10cm between plants and 40cm between double rows, as recommended by Lemma and Shimeles (2003). Each experimental plot accommodated six double rows with17 plants in each row and a total of 204 plants. The distance between plots and blocks (replications) was 0.5m, and 1 meter respectively. Therefore a total of 448.96 m^2 area of land was used for the experiment.

Table 2.Treatment combinations used for the study area

Treatment number	Variety Name	NPSB and Urea kg ha^{-1}
1	Bombay Red	0
2	Nafid	0
3	Nafis	0
4	Nasik Red	0
5	Bombay Red	195 + 128
6	Nafid	195 + 128
7	Nafis	195 + 128
8	Nasik Red	195 + 128
9	Bombay Red	244 + 128
10	Nafid	244 + 128
11	Nafis	244 + 128
12	Nasik Red	244 + 128
13	Bombay Red	293 + 128
14	Nafid	293 + 128
15	Nafis	293 + 128
16	Nasik Red	293 + 128

3.4. Experimental Procedures and Field Management

Seeds of the four varieties of onion were drilled in rows on 1m x 5m well prepared seedbed at seeding rate of 4 $kgha^{-1}$ to raise seedlings (EIAR, 2012).The management of seedlings such as watering, cultivation, fertilization, control of diseases and insect pests were done as per the recommendation (EARO, 2004).

The experimental land was prepared well in accordance with a standard practice and the large clods of soil were broken down in order to have fine tilth before planting of the seedlings. After 50 days of sowing and when seedlings attained the 3 to 4 leave stage or when the seedlings attain the estimated height of 12 to 15 cm, healthy and uniform seedlings were transplanted in to well prepare experimental field as recommended by (Lemma and Shimeles, 2003).

Replanting of dead seedlings was done one week after transplanting. The whole NPSB blended fertilizer rates were applied during transplanting for all treatments except control. Whereas, Urea was side dressed in two split at equal amount after 25 and 45 days of transplanting (EARO, 2004).Other agronomic practices such as weeding, hoeing, disease and pest control were applied to all treatments as per recommendations.

3.5. Soil Sampling Procedure and Analysis

To know the fertility status of soil, soil samples were taken randomly from the experimental field at five spots diagonally at the depth of 20 cm before planting and mixed to make a soil composite. Physical and chemical properties like soil texture, pH, Cation Exchange Capacity (CEC), organic matter (%),Organic carbon (%), available phosphorus (mg/kg (ppm), available sulfur (mg/kg (ppm) and available boron (mg/kg (ppm) of the composite soil were analyzed at Wolkite and Areka soil laboratory centers.

The pH of the soil was determined by 1:2.5 soils to water ratio using a glass electrode attached to a digital pH meter (Black, 1965). Soil textural class was determined by Bouzoukis hydrometer method (Bouzoukis, 1962). Organic matter content of the soil was determined by Walkley and Black method (Walkley and Black, 1934). Organic carbon content of the soil was determined by the volumetric method based on the oxidation of organic carbon with acid potassium di-chromate (KCO) medium (Walkley and Black, 1934).

Available phosphorus (ppm) was determined by the Olsen's method (Bray and Kurtz, 1954). Available sulfur (meq/l SO_4^{-2}) was determined by mono-calcium phosphate extraction method (Hoeft *et al*.1973), and available boron was determined using hot water method (Havlin *et al*,1999).Cation Exchangeable Capacity (CEC) was determined titrimetrically by distillation of ammonia that was displaced by Na (Sahlemedhin and Taye, 2000).

3.6. Data Collection

3.6.1. Growth parameters

The data for growth parameters were collected from middle four double rows of each plot as follows:

Plant height (cm): Plant heights of ten randomly selected plants were measured from the soil surface to the top of the longest leaf using a ruler at physiological maturity and the mean values computed.

Leaf length (cm): The longest leaves of ten randomly selected plants at physiological maturity were measured from the point of their emergence using ruler and expressed as a mean value in centimeter (cm).

Leaf number: Number of leaves of ten randomly selected plants per plot was counted at physiological maturity and the mean values computed.

Days to 80% maturity (days): The number of days elapsed from the time of transplanting up to the date when 80% of plants became dry and collapsed at the neck was counted and the mean values computed and used for further analysis.

3.6.2. Yield and yield related parameters

Bulb weight (g): The mean bulb weight of ten randomly selected bulbs at harvest was taken (Guesh, 2015).

Bulb diameter (cm): The mean diameter of the bulb at harvest was computed by measuring the diameters at the middle of ten randomly selected bulbs in each plot using caliper.

Marketable bulb yield (t/ha): Bulbs free of mechanical damage, disease and insect pest damages, uniform in color and medium to large in size (20 - 160 g) were consider as marketable .The weight of such bulbs from the net plot area of each plot was measured in kilogram and expressed as ton per hectare (Lemma and Shimeles, 2003).

Unmarketable bulb yield (t/ha): Harvested bulbs under sized (<20g), oversized (>160g), misshaped, decayed, discolored, diseased and physiologically disordered were considered as unmarketable (Lemma and Shimeles, 2003). The weight of such bulbs obtained from the net plot area of each plot was measured in kilogram and expressed as ton per hectare.

Total bulb yield (t/ha): Total yield of onion was obtained by adding marketable and unmarketable bulb yields and expressed as ton per ha (Guesh, 2015).

3.6.3. Partial budget analysis

The Partial budget analysis was computed using the procedure described by CIMMYT (1988) to identify economically attractive combination of NPSB fertilizer and onion varieties. The cost of NPSB, onion varieties and labor cost involved for this activity was considered as variable costs. The net benefits and other economic analysis were based on the formula developed by CIMMYT (1988).

Adjusted grain yield (AGY) (kg ha^{-1}): AGY was the average yield adjusted down wards by a 10% to reflect the difference between the experimental yield and yield of farmers.

Gross field benefit (GFB)(ETB ha^{-1}): GFB was computed by multiplying field/farm gate price that farmers receive for the crop when they sell it as adjusted yield. GFB=AGY ×field/farm gate price for the crop.

Total variable cost (TVC)(ETBha^{-1}) : TVC was calculated by summing up the costs that vary, including the cost of NPSB fertilizers at the time of planting. The costs of other inputs and production practices such as labor cost for land preparation, planting, weeding and harvestings were considered the same for all treatments or plots.

Net benefit (NB) (ETBha^{-1}): NB was calculated by subtracting the total variable costs (TVC) from gross field benefits (GFB) for each treatment as: NB=GFB– TVC.

Marginal rate of return (MRR %) :was calculated by dividing change in net benefit by change in cost which was the measure of increasing in return by increasing input.

3.7. Statistical Analysis

Analysis of Variance (ANOVA) was done by using the Statistical Analysis System (SAS) Software version (9.3). Mean separation between treatments was done using Least Significance Difference (LSD) at 5% probability (Gomez and Gomez, 1984).Correlation analysis among parameters was also carried out.

4. RESULTS AND DISCUSSION

4.1. Soil Sample Analysis

4.1.1. Soil physical properties

The soil texture of the experimental site was 36% sand, 36% silt, and 28% clay (Table 3).The textural class of the soil was found to be clay loam based on the soil textural triangle of the International Society of Soil Science system (Rowell, 1994).

4.1.2. Soil chemical properties

The chemical property of the experimental soil was as shown in Table 3**.**The pH value of the soil was 6.3, which is slightly acidic (Hazelton and Murphy, 2016). PH values classified as extremely acid if pH<4.0, very strongly and strong acid 4.0-5.5, moderately acid and neutral l5.5-7.3, slightly and moderately alkaline 7.3-8.5, and pH values >8.5 strongly and very strongly alkaline. The optimum pH for onion production ranges between 6 and 8 (Nikus and Mulugeta, 2010).

The CEC of the soil was 29.2 cmol kg^{-1} soils, which is under high CEC category. According to Landon (1991), top soils having CEC greater than 40 cmol kg^{-1} are rated as very high and 25-40 cmol kg^{-1} as high, and 15-25, 5-15 and < 5 cmol kg^{-1} of soil are classified as medium, low and very low, respectively, in CEC. The soil organic matter content of the study area was 3.83%, which is under high range as described by Charman and Roper (2007). The rating is < 0.5% as extremely low , 0.7-1% as very low,1-1.7% as low,1.7-3% moderate, 3-5.15% high and >5.15% very high. Accordingly the experimental field was good structural condition for onion production. The soil organic carbon content of the study area was 2.22%, which is under high range as described by Hazelton and Murphy (2007). The rating is < 0.4%extremely low, 0.4-0.6% very low,0.6-1% low,1-1.8% moderate, 1.8-3% high and >3% very high.

The available P content of the experimental site was 6.0mg kg^{-1}. According to Hazelton and Murphy (2016), the range of phosphorus in Bray method is < 7, 8-19, 20-39, 40-58 and >59 mg kg^{-1}soilwas very low, low, medium, high and very high, respectively. Hence the study area falls under very low P level, indicating the application of external source of phosphorus is important.

Available sulfur value of the study area was 14.6 mg kg^{-1}.According to Horneck *et al*. (2011) sulfur values categorized under medium range. The classification showed soils with value < 2 very low, 2-5 low, 5-20 medium and > 20 mg kg^{-1}high. Hence application of maintenance rate of sulfur fertilizer is needed for the study area.

Available boron value of the study area was also 0.44 mg kg^{-1}. According to Benton (2003) report, the critical levels of boron value for most Ethiopian soils is 1.1 - 2 mg kg^{-1} , below this range indicated as boron deficiency whereas ranges low (0.3- 1 mg kg^{-1}), optimum (1.1-2 mg kg^{-1}), high (2.1- 4 mg kg^{-1}) and very high >4 mg kg^{-1}).

Table 3.Soil physical and chemical characteristics of study area

Soil Properties	Values	Rating	Source
Ph	6.3	Slightly acidic	Hazelton and Murphy (2016)
Organic matter (%)	3.83	High	Charman and Roper(2007)
Organic Carbon (%)	2.22	High	Hazelton and Murphy (2016)
Available P (mg/kg)	6.0	Very low	Hazelton and Murphy (2016)
CEC (cmol (+)/kg)	29.2	High	Landon (1991)
Available S (mg/kg)	14.6	Medium	Horneck et al, (2011)
Available B (mg/kg)	0.44	Low	Benton (2003)
Particle size distribution			
Sand (%)	36		
Silt (%)	36		
Clay (%)	28		
Textural class		clay loam	Rowell (994)

P-phosphorous: CEC-cation exchange capacity: S –sulfur: B-boron

4.2. Growth Parameters

4.2.1. Plant height (cm)

Analysis of variance revealed that the main effects of varieties and NPSB blended fertilizer significantly (P<0.01) influenced plant height of onion. However, the two factors did not interact to influence plant height (Appendix Table 1).

The highest mean plant height (56.55 cm) was recorded from the Nafis variety which was statistically at par with the mean plant height of Bombay Red, while the lowest (49.61 cm) was from Nasik Red and statistically par with Nafid (Table 4).The result is in parity with the finding of Demisie and Tolessa (2018), who reported the highest plant height from Nafis variety, as compared to Nasik Red, Adama Red and Melkam varieties. Ghaffoor *et al*. (2013) also indicated the presence of significant plant height differences among onion varieties.

On the other hand the highest plant height (62.64cm) was recorded with the application of 293 kg ha^{-1} NPSB blended fertilizer, while, the lowest plant height (42.47cm) was recorded from control treatment (0 kg ha^{-1} NPSB).

The increase in plant height with the addition of higher nitrogen fertilizer level could be attributed to more availability of the nutrient which enhances protein synthesis lead to increased accumulation of carbohydrates and this in turn, may have resulted in increased plant growth such as leaf number and leaf length (Rizk *et al.*,2012).The result is consistent with the findings of Morsy *et al. (*2012), Nasreen *et al*.(2007), who reported significant increment of onion plant height with increased nitrogen fertilizer rates. Phosphorus enhances photosynthesis, nitrogen fixation and encouraged root growth because it has a vital role in energy transfer held as a part of the chemical structures of ADP and ATP that drives the chemical reactions within the plant. Sulfur is important building block of protein and a key ingredient in the formation of chlorophyll. Bloem *et al. (*2004) also reported that onion is a sulfur loving plant. Boron is also an essential micronutrient that is necessary for normal cell division, nitrogen metabolism, protein formation, and phosphorus uptake. Assefa *et al.* (2013) reported that plant height increased with an increase in the combined application of N, P, S, and Zn fertilizers. Hence the application of these nutrients in optimum rate influenced the height of onion in the current study.

Table 4.Effect of variety and NPSB blended fertilizer rate on plant height of onion

Onion Varieties	**Plant height (cm)**
Bombay Red	55.79[a]
Nafid	50.02[b]
Nafis	56.55[a]
Nasik Red	49.61[b]
LSD (5%)	3.11
NPSB fertilizer rates (kg ha^{-1})	
0	42.47[c]
195	52.42[b]
244	54.44[b]
293	62.64[a]
LSD (5%)	3.11
CV (%)	7.06

Means followed by the same letter in a column are not significantly different at 5% probability level

4.2.2. Leaf length (cm)

The analysis of variance revealed that the main effect, varieties, and the interaction of varieties and NPSB blended fertilizer rate significantly (P<0.05) influenced leaf length of onion. Whereas, the main effect, NPSB fertilizer rate was highly significant (P<0.01)to influence leaf length of onion (Appendix Table 1).

The maximum mean leaf length value (52.5 cm) was recorded from the Nafis variety at the highest rate of NPSB (293 kg ha^{-1}) blended fertilizer , while, the minimum mean leaf length value (35.53cm) was recorded from variety Bombay Red at control fertilizer treatment (Tabel.5).

The results is in agreement with the finding of Birhanu (2016), who reported a positive effect of nitrogen on leaf length, probably due to its role in chlorophyll, enzymes, and protein synthesis. Similarly, Jilani (2004) and Rao *et al. (*2013) reported the increased leaf length of onion at higher rate of nitrogen fertilization. The increased leaf length due to phosphorus application was reported (Gustfson *et al.,* 2010), probably attributed to the role of phosphorus to form good root systems and strong stem. Fatma *et al.* (2014) reported the application of sulfur containing fertilizer positively affected all onion growth variables. Similarly the current study is in accord with Nigatu *et al. (*2018) who reported that the longest leaves were obtained from the application of 136.5:119.6:22 kg ha^{-1} of N: P_2O_5:S fertilizer. Ghaffoor et *al*. (2013) also reported that the application of phosphorus at 100 kg ha^{-1} Produced higher onion leaf length.

4.2.3. Leaf number

The main effect of varieties as well as NPSB blended fertilizer rate significantly ($P<0.01$) influenced the leaf number of onion. Similarly, the interaction effect of varieties and NPSB blended fertilizer application significantly ($p<0.05$) influenced the leaf number of onion (Appendix Table 1).

The highest mean leaf number (14.27) was produced from Nafis variety in response to application of the highest rate of NPSB blended fertilizer (293 kg ha^{-1}), while, the least number of leaves per plant (6.17) was recorded from Nasik Red variety at the control NPSB which was statistically at par with the combined effect of Nafid variety and control NPSB (Table 5).

The increase in leaf number per plant at a higher rate of NPSB fertilizer could be attributed to the availability of macro and micronutrients that permit leaves to grow vigorously; Nitrogen and sulfur fertilization had the potential to increase nutrients availability in the soil and thus enhance the uptake of nutrients by the plant (Molla *et al*., 2020). The result of the present study is in lined with the finding of Abdissa and Pant (2011), who reported significant influence of nitrogen fertilization to number of leaves produced by the onion plant. Similarly, Vachhani and Patel (1993) reported that the number of onion leaves per plant was highest with the application of 150 $kgha^{-1}$nitrogen; Nigatu (2016) reported the highest number of leaves recorded as a result of the combined application of 105:92:16.95 N: P_2O_5: S and the least number of leaves from unfertilized plants. The application of sulfur and Boron is also reported to increase the number of leaves per plants (Gessesew, 2015; Manna *et al.*, 2014).

4.2.4. Days to 80% of physiological maturity

The result of the analysis of variance indicated days to maturity was significantly ($P < 0.01$) affected by the main effect of onion varieties and NPSB blended fertilizer rate.

Moreover the interaction effects of varieties and NPSB blended fertilizer rate also significant ($p<0.05$) effect on days to maturity (Appendix Table 1).

The earliest days to physiological maturity (93 days) was recorded from the combined effect of Nafid variety and control (0) NPSB fertilizer, which was statistically at par with the combined effect of Nafis variety and control (0) NPSB(Table 5). Whereas, the longest days to physiological maturity (122 days) was recorded from treatment combination of variety Bombay Red and 293 kg ha^{-1}NPSB blended fertilizer. The possible reason for the highest days of maturity at 293 kg ha^{-1} NPSB could be associated with the highest nitrogen found in the NPSB fertilizer that extend the vegetative growth period of plants, while delaying maturity.

The results are in agreement with the findings of various researchers who observed extended vegetative growth of various vegetables including onion with higher rates of NPSB fertilizers as well as nitrogen (Abdissa and Pant, 2011; Weldemariam *et al*., 2015). Similarly, Gueshu (2015) and Molla *et al.* (2020), observed that too much nitrogen promoted excessive vegetative growth and delayed maturity. Early maturity at the non-fertilized level might be due to insufficient supply of nutrients that shorten the duration of vegetative growth; thus entered into the reproductive phase and matured earlier. Azoom *et al.* (2014) reported significant differences among eight onion varieties for days to bulb maturity; the significant difference observed on physiological maturity among the varieties subjected to varying levels of fertilizer rates might be due to their genotypic difference.

Table 5.Interaction effects of Varieties and NPSB blended fertilizer rate on leaf length, leaf number and days to physiological maturity of onion

Varieties	NPSB kg ha^{-1}	Parameters		
		Leaf length (cm)	Leaf number per plant	Physiological maturity (80%)
Bombay Red	0	35.53^{j}	7.5^{h}	105.3^{ghi}
Nafid		38.4^{ij}	6.47^{i}	93.0^{l}
Nafis		41.43^{hi}	8.17^{h}	94.3^{l}
Nasik Red		39.67^{hij}	6.17^{i}	98.3^{k}
Bombay Red	195	43.23^{efg}	9.57^{g}	109.3^{ef}
Nafid		42.7^{fgh}	10.43^{f}	100.3^{jk}
Nafis		43.7^{defg}	11.13^{ef}	102.0^{ij}
Nasik Red		42.4^{fgh}	9.1^{g}	104.0^{ghi}
Bombay Red	244	46.8^{bcd}	12.27^{cd}	115.0^{c}
Nafid		46.4^{bcde}	12.6^{bc}	103.3^{hij}
Nafis		45.23^{cdef}	12.63^{bc}	106.0^{fgh}
Nasik Red		42.83^{fgh}	11.1^{ef}	114.3^{cd}
Bombay Red	293	49.2^{ab}	13.23^{b}	122.0^{a}
Nafid		47.27^{bc}	12.77^{bc}	107.0^{fg}
Nafis		52.5^{a}	14.27^{a}	111.0^{de}
Nasik Red		47.73^{bc}	11.77^{de}	118.0^{b}
LSD (5%)		3.38	0.81	3.56
CV (%)		4.6	4.59	2

Means followed by the same letter in a column are not significantly different at 5% probability level

4.3. Yield and Yield Related Traits

4.3.1. Bulb weight (g)

The main effect of varieties and NPSB blended fertilizer rate significantly ($P<0.01$) influenced the bulb weight of onion .Similarly, the interaction effect of varieties and NPSB fertilizer significantly ($p<0.05$) influenced the bulb weight of onion (Appendix Table 2).

The interaction of variety Nafis and 293 kg ha^{-1} NPSB fertilizer resulted in the highest mean bulb weight (98.47 g) of onion, which was statistically at par with the value recorded from Bombay Red variety at the same rate of NPSB fertilizer. Whereas the lowest bulb weight (39.73 g) was recorded from the Nasik Red Variety at zero rate of NPSB fertilizer, which was statistically at par with Nafid variety at control (0) rate of NPSB fertilizer (Table 6).

Increasing the rate of NPSB fertilizer progressively increased the average bulb weight of the onion across the varieties. The possible reason could be associated with supply of enough plant nutrients required for growth and development of onion plants that lead to increased accumulation and translocation of assimilates from leaves to bulb. According to Singh *et al.* (2004),the increase in bulb weight could be due to the increased uptake of nutrients and build up of sufficient photosynthesis enabling the increased in size of bulbs (length and breadth), ultimately resulting in the increased average bulb weight.

The current result in lined with Fikre *et al. (*2021) who reported the highest average bulb weight from Nafis variety at 187.5 kgh^{-1} NPSB than Nasik Red and Adama Red varieties. On the other hand, onion plants supplied with 105:119.6:22 kg ha^{-1} N: P2O5: S fertilizer rate gave the highest bulb weight over the control (Muluneh *et al.*, 2018). Similarly, Ahmed *et al*. (1988) reported that the application of sulfur up to 24 kg ha^{-1} significantly improved the weight of onion bulbs, which was positively correlated with the onion yield.

4.3.2. Bulb diameter (cm)

The main effect of varieties and NPSB blended fertilizer significantly ($P<0.01$) influenced the bulb diameter of onion. Similarly, the two factors interacted to influence bulb diameter significantly ($P < 0.01$) (Appendix Table 2).

The increasing rate of NPSB application consistently increased the mean bulb diameter across different onion varieties. Thus, the highest mean bulb diameter (5.89 cm) was recorded in response to the use of Nafis onion variety and application of 293 kg ha^{-1} NPSB which was statistically at par with the mean bulb diameter of Bombay Red at 293 kg ha^{-1} NPSB. Whereas, the lowest mean bulb diameter (3.07cm) was recorded from combination Nafid variety and zero rate of NPSB fertilizer which was statistically at par with Nasik Red variety at control NPSB fertilizer (Table 6).

Muhammad *et al. (*2011) reported increased bulb diameter of onion due to increasing rate of nitrogen fertilizer. According to Ghaffoor *et al. (*2013), maximum bulb diameter of onion was recorded at rate 120 kg ha^{-1}nitrogen, while application of 50 kg N ha^{-1}increased the bulb diameter by about 19.81% as compared to the control without affecting bulb length. This could be due to the activities of N in different physiological and metabolic processes which result in increased in dry matter production (Birhanu, 2016).

Table 6.Interaction effects of Varieties and NPSB blended fertilizer rate on bulb weight and bulb diameter of onion

Varieties	NPSB kg ha^{-1}	Parameters	
		Bulb weight (g)	Bulb diameter (cm)
Bombay Red	0	47.87^{h}	3.53^{ef}
Nafid		39.87^{i}	3.07^{g}
Nafis		48.53^{h}	3.51^{ef}
Nasik Red		39.73^{i}	3.21^{g}
Bombay Red	195	57.50^{g}	5.03^{cd}
Nafid		49.13^{h}	3.60^{e}
Nafis		67.13^{f}	4.91^{d}
Nasik Red		47.93^{h}	3.62^{e}
Bombay Red	244	73.33^{de}	5.28^{bc}
Nafid		77.27^{cd}	5.12^{bcd}
Nafis		82.13^{bc}	5.36^{bc}
Nasik Red		69.20^{ef}	5.11^{bcd}
Bombay Red	293	93.0^{a}	5.80^{a}
Nafid		86.0^{b}	5.41^{b}
Nafis		98.5^{a}	5.89^{a}
Nasik Red		83.5^{b}	5.43^{b}
LSD (5%)		6.04	0.36
CV (%)		5.46	4.71

Means followed by the same letter in a column are not significantly different at 5% probability level

4.3.3. Marketable bulb yield (t ha^{-1})

The analysis of variance showed that the main effect of varieties and NPSB blended fertilizer level and also their interaction effect significantly ($P < 0.01$) influenced the marketable bulb yield of onion (Appendix Table 3).

The highest marketable bulb yield (33.5 t ha^{-1}) was obtained from Nafis onion variety at NPSB fertilizer rate of 293 kg ha$^{-1.}$ However, the lowest marketable bulb yield (8.27t ha^{-1}) was obtained from Nasik Red variety at nil NPSB fertilizer rates, which was statistically similar with marketable bulb yields obtained from Nafid variety at zero kg ha^{-1} NPSB fertilizer rate (Table 7).

Increasing the use of NPSB fertilizer across all varieties increased the marketable bulb yield in the present study area. The probable reason for the increased marketable bulb yield could be the presence of plant nutrients that are required from improved growth and development of onion plants that in turn increased the marketable bulb yield. Whereas, variation observed among onion varieties might be due to genetic potential difference.

Kasech and Rahel (2018) reported that variety Nafis provided the highest marketable bulb yield (36.24 t ha^{-1}).Rajcumar (1997) also reported significant differences on marketable yields of onion varieties ranging from 8.4-38.7 t ha^{-1}.This variation probably due to the fact that cultivar may performs differently under the same environment due management difference or due to the genetic makeup of the cultivars and the interaction effects of the two (Yemane *et al*., 2014).Jilani (2004),also reported significant difference within varieties for marketable bulb yield in onion.

This result also in lined with the findings of Muluneh (2016) who reported that onion marketable yield significantly increased as blended fertilizer rates increased. Fikre *et al. (*2021*)* reported the higher marketable bulb yield obtained in response to the application of 185.7 kg ha^{-1} NPSB at the Nafis variety whereas the lower marketable bulb yield obtained from zero application of NPSB fertilizer with a Nasik Red variety.

Manna *et al,* (2014) reported that foliar application of boron with zinc significantly increases the marketable and total yield of onion. Ostaszewska (2011) reported that sulfur and nitrogen stimulate the enzymatic actions and chlorophyll formations, which promote the growth and development of the plant leading to high yielding performance.

4.3.4. Unmarketable bulb yield (t ha^{-1})

The main effect of varieties as well as that of NPSB blended fertilizer rate significantly ($P<0.01$) influenced unmarketable yield of onion .Similarly, the interaction effect of varieties and fertilizer rate significantly ($p<0.05$) influenced the unmarketable yield of onion (Appendix Table 3).

The highest unmarketable yield (1.44tha^{-1}) was recorded from the use of Nasik Red variety and control (zero) NPSB fertilizer, which was statistically at par with Nafid variety at control (zero) NPSB fertilizer (Table 7). On the other hand, the lowest unmarketable bulb yield was obtained both when onion variety (Nafis) was combined with 293 kg ha^{-1} NPSB blended fertilizer.

The result was in accorded with Kitila *et al*. (2022), stated the combined NPS fertilizer levels increase from 0 kg ha^{-1} to 200 kg ha^{-1}, the non-marketable yield of onion variation has been reduced. This may be due to an increasing in NPS fertilizer levels and an increase in the amount of nitrogen fertilizer, which reduces the yield of onion tuber that can be sold for the progressive role, and it plays in increasing the new bulb weight ratio. Similarly, Kibebew *et al.* (2021) who reported that the maximum amount of unsold onion bulb yields was obtained at zero kg^{-1}of NPS fertilizer. Maximum application of N at rate of 150 kg ha^{-1} decreased the unmarketable bulb yield per hectare by about 52.1 % as compared to the unfertilized plot. Sub optimal supply and low nitrogen levels have been associated with early bulb formation, plants can be severely stunted, with bulbs size and marketable yields reduced in onion (Muluneh, 2019).

Similarly Brewster (1994) reported that under sub-optimal supply of nitrogen, the marketable yields of onion and shallot can be severely reduced. Likewise, Negash *et al*. (2009) and Jilani (2004) indicated that nil nitrogen fertilizer rates resulted in more unmarketable bulb yield.

4.3.5. Total bulb yield (t ha^{-1})

The analysis of variance revealed that the main effect and interaction effect were significantly ($p<0.01$) influenced the total bulb yield of onion (Appendix Table 3).

The highest total bulb yield (34.02 t ha^{-1}) was recorded from Nafis variety that received 293 kgha^{-1} NPSB blended fertilizer rates. While, the least total bulb yield (9.70t ha^{-1}) was obtained from Nasik Red variety at zero (control) NPSB fertilizer rate (Table 7).

Increasing the rate of NPSB fertilizer from 0 to 293 kg ha^{-1} increased the total bulb yield of onion significantly and linearly across all varieties. The increased in the yield of onion is probably associated with the combined effects of plant nutrients (N, P, S and B) found in NPSB fertilizer. The effect of sulfur and nitrogen in stimulating the enzymatic actions and chlorophyll formation which promote the growth and development leading to high yielding performance of plants was reported (El-Shafie and El-Gamaily, 2002).also reported that an adequate supply of nutrients to plants is associated with vigorous vegetative growth resulting higher productivity of crops.

The result in lined with Molla *et al. (2020),* who recorded the highest total bulb yield with application of 325.36 kg ha^{-1} NPSB fertilizer rate, and Bombay Red variety whereas the least total bulb yield was recorded in the control treatment with Adama Red variety. Similarly the results are also consistent with the finding of Fikre *et al*. (2021), who reported that the application of 187.5 kg ha^{-1}NPSB with the use of Nafis variety was shown the maximum total bulb yield of onion, whereas the least total bulb yield was recorded in the control treatment with Nasik Red variety. Moreover Muluneh *et al*. (2018), who was recorded onion plants supplied with 105:119.6:22 kg ha^{-1} (N: P_2O_5: S) fertilizer rate gave the highest total bulb yield over the control. Similarly Tekeste *et al. (*2018),the maximum total bulb yield obtained in response to the combined application of 103.5 kg N ha^{-1} and 138 kg P_2O_5 $ha^{-1}$and lowest total and marketable bulb yields was recorded at 0 kg N and P_2O_5 $ha^{-1.}$

Similarly, Assefa *et al.,* (2013), reported that combined effect of the contributions of nitrogen to chlorophyll, enzymes, and protein synthesis; as phosphorus is essential for root growth, phosphor proteins, and phosphor-lipids that contribute for yield increment. Similarly, sulfur is an important nutrient that increases the formation of vegetative structures for nutrient absorption and photosynthesis and increases the production of assimilates to fill the sinks, resulting in increased yield of onion.

Moreover, because onion is a sulfur-loving vegetable (Bloem *et al.*, 2004), the increased bulb yield of onion could be probably associated with the positive effect of sulfur contained in NPSB fertilizer. According to Marschner (1995), application of sulfur containing fertilizer like NPS modifies soil pH, improves soil-water relation and increases the availability of plant nutrients like P, Fe, Mn and Zn, which may increase the bulb yield of onion.

Table7.Interaction effects of varieties and NPSB blended fertilizer rate on marketable, unmarketable and total bulb yield of onion

Varieties	NPSB kg ha^{-1}	Parameters		
		marketable bulb yield (t ha^{-1})	unmarketable bulb yield (t ha^{-1})	total bulb yield (t ha^{-1})
Bombay Red	0	9.95^{j}	1.13^{b}	11.09^{i}
Nafid		8.35^{k}	1.36^{a}	9.72^{j}
Nafis		10.29^{j}	$1.04b^{c}$	11.33^{i}
Nasik Red		8.27^{k}	1.44^{a}	9.70^{j}
Bombay Red	195	15.95^{h}	0.89^{ed}	16.84^{fg}
Nafid		15.35^{h}	0.93^{d}	16.28^{g}
Nafis		17.19^{g}	0.83^{ef}	18.02^{f}
Nasik Red		13.96^{i}	0.96^{cd}	14.92^{h}
Bombay Red	244	22.29^{e}	0.8^{ef}	23.09^{d}
Nafid		21.68^{e}	0.81^{ef}	22.49^{de}
Nafis		26.71^{d}	0.78^{gf}	27.49^{c}
Nasik Red		20.41^{f}	0.88^{ed}	21.29^{e}
Bombay Red	293	29.39^{b}	0.56^{i}	29.95^{b}
Nafid		28.05^{c}	0.66^{h}	28.7^{c}
Nafis		33.50^{a}	0.52^{i}	34.02^{a}
Nasik Red		27.34^{cd}	0.71^{g}	28.05^{c}
LSD (5%)		1.23	0.1	1.22
CV (%)		3.82	6.4	3.61

Means followed by the same letter in a column are not significantly different at 5% probability level

4.4. Correlation Coefficient Analysis

Correlation coefficient is a statistical measure, which is used to find out the degree and direction of relationship between two or more variables. The correlation values showed the apparent association of the parameters of the crop with each other. The values of phenotypic correlation coefficient among yield and its attributes are as presented in Table.8

Results of the correlation analysis revealed that total bulb yield was highly significant ($P<0.01$) and positively correlated with plant height (r=0.86**), leaf length (r=0.86**), leaf number (r=0.93**), 80% days to maturity (r=0.72**), bulb weight (r=0.97**), bulb diameter (r=0.91**). However, total bulb yield was highly but negatively correlated to unmarketable bulb yield (r=-0.89**). Similarly, plant height was positively correlated and highly significant with leaf length (r=0.74**), leaf number (r=0.83**), days to 80%

maturity (r=0.68**), bulb weight (r=0.86**), bulb diameter (r=0.87**), marketable bulb yield (r=0.86**), total bulb yield (r=0.86*). Whereas, plant height was highly but negatively correlated to unmarketable bulb yield (r=-0.88**).

Table 8.Correlation analysis between growth, yield and yield related parameters of onion

	PH	LL	LN	DM	BW	BD	MBY	UMBY	TBY
Ph	1.00								
LL	0.74**	1.00							
LN	0.83**	0.84**	1.00						
DM	0.68**	0.60**	0.65**	1.00					
BW	0.86**	0.83**	0.92**	0.71**	1.00				
BD	0.87**	0.81**	0.89**	0.76**	0.93**	1.00			
MBY	0.86**	0.86**	0.93**	0.72**	0.97**	0.91**	1.00		
UBY	-0.88**	-0.78**	-0.92**	-0.66**	-0.89**	-0.86**	-0.90**	1.00	
TBY	0.86**	0.86**	0.93**	0.72**	0.97**	0.91**	1.00	-0.89**	1.00

Whereas, PH,LL, LN, DM, BW,BD,MBY,UMBY & TBY = Plant height, Leaf length, Leaf number, Days to maturity, Bulb weight, Bulb diameter, Marketable bulb yield, Unmarketable bulb yield and Total bulb yield respectively.** indicate significance at P<0.01 LSD tests

4.5. Partial Budget Analysis

Partial budget is a method of organizing experimental data and information about the costs and benefits of various alternative treatments. It is the process of examining only those costs, returns and resource needs that change with a proposed adjustment. A partial budget is a way of calculating the total costs that vary and the net benefits of each treatment (CIMMYT, 1988).

In this study, partial budget analysis was computed by considering total variable cost, net benefit analysis and marginal rate of return. The different costs of this experiment which include cost for fertilizer, seed, and labor cost were used for this calculation. The purchasing price of NPSB, Urea and seeds were 39.88 Birr kg^{-1}, 41.01 Birr kg^{-1} and 5607 Birr kg^{-1}respectively. The cost for daily labor during the season was 150 Birr per day. The field price of onion during the harvesting season was 26 birr kg^{-1}**.**The total variable costs were subtracted from gross benefit to obtain net benefit.

Accordingly, the highest net benefit of Birr 571054with highest cost was recorded from the combination of Nafis variety and 293 kgha^{-1}of NPSB with marginal rate of return 7803% which was followed by net benefit of Birr 474880 from Bombay Red variety and 293 kgha^{-1} of NPSB with the marginal rate of 8168%. However, the highest net benefit of Birr 414255 with least cost production of about Birr 210759 were obtained from the use of Nafis variety and 244 kgha^{-1} of NPSB with marginal rate of return (10986%).

The minimum acceptable marginal rate of return (MARR %) should be between 50% and 100% CIMMYT (1988). Thus, the current study indicated that marginal rate of return is higher than 100% except control treatments (Table 9). This showed that except control all the treatment combinations are economically important as per the MRR is greater than 100%. Hence, the most economically attractive combinations for small scale farmers with low cost of production and higher benefits were in response to the use of Nafis variety and application of 244 kg NPSB ha^{-1}. However, for intensive producers the use Nafis variety and application of 293 kg ha^{-1}NPSB is also profitable with higher cost and highest net benefit could be recommended second option for the study area.

Table 9.Partial budget and MRR analysis for varieties and NPSB fertilizer rate on marketable yield.

Varieties	NPSB (kg ha-[1])	Average marketable yield (ton ha[1])	Average marketable yield (kg ha[1])	Adjusted marketable yield (kgha[1])	Gross Field benefit (ETB)	Total variable cost(ETB)	Net benefit (ETB)	Marginal rate of return (%)
Bombay red	0	9.95	9953	8958	232907	185648	47259	-
Bombay red	195	15.95	15947	14352	373153	208750	164403	507
Bombay red	244	22.29	22287	20058	521509	210759	310750	7283
Bombay red	293	29.39	29387	26448	687649	212769	474880	8168
Nafid	0	8.35	8353	7518	195467	185648	9819	-
Nafid	195	15.35	15350	13815	359190	208750	150440	609
Nafid	244	21.68	21677	19509	507235	210759	296476	7267
Nafid	293	28.05	28047	25242	656293	212769	443524	7318
Nafis	0	10.29	10287	9258	240709	185648	55061	-
Nafis	195	17.19	17190	15471	402246	208750	193496	599
Nafis	244	26.71	26710	24039	625014	210759	414255	10986
Nafis	293	33.50	33497	30147	783823	212769	571054	7803
Nasik Red	0	8.27	8270	7443	193518	185648	7870	-
Nasik Red	195	13.96	13960	12564	326664	208750	117914	476
Nasik Red	244	20.41	20413	18372	477671	210759	266912	7415
Nasik Red	293	27.34	27340	24606	639756	212769	426987	7966

5. SUMMARY AND CONCLUSION

Onion (*Allium cepa* L.) is one of the most important vegetable crops commercially grown in the world. It is a high value and high income generating vegetable crops for most farmers in Ethiopia which is widely produced in small scales and by commercial growers. Onion is considerably important in the daily Ethiopian diet which the bulbs and the lower stem sections are the most popular as seasonings or as vegetables in stews.

The enhancement of onion production and productivity can be related with different growth factors. Thus, the use of appropriate agronomic management has an undoubted contribution to increased crop yield. Several constraints are associated with the production of onion. Among those production problems the low yield because of non-optimal agronomic practices, unavailability and high cost of seed, the prevalence of diseases and insect pests, lack of improved varieties and more improved production technologies are the majors. Hence, Successful onion production in the area depends on the selection of varieties and appropriate fertilizer rates are among the key agronomic practices which affect yield and quality of onion bulbs.

The experiment was conducted during 2022 in Gurage Zone Cheha district with objectives of assessing growth and yield response of onion varieties to NPSB fertilizer rates. Four onion cultivars (Bombay Red, Nafid, Nafis and Nasik Red) and four NPSB fertilizer rates (0, 195, 244, 293 $kgha^{-1}$) were arranged as 4 x 4 factorial treatments and laid out as a randomized complete block design (RCBD) with three replications.

All yield and yield related traits were significantly influenced by the interaction of varieties and NPSB blended fertilizer rates except plant height and that were significantly influenced by main effects of varieties and NPSB fertilizer rates. The tallest plant height, leaf length, leaf number per plant was recorded in the combination of the Variety Nafis and 293 kg ha^{-1} NPSB fertilizer; the longest days to maturity was recorded in the combination of Variety Bombay Red and 293 kg ha^{-1} NPSB fertilizer. Moreover, the highest bulb weight, wider bulb diameter, highest marketable bulb yield and highest total bulb yield were recorded at a treatment combination of the variety Nafis and 293 kgh^{-1} NPSB fertilizer.

The partial budget analysis indicated that, the highest net benefit of Birr 571054 with highest cost was recorded from the combination of variety Nafis and NPSB blended fertilizer at a rate of 293 kg ha^{-1} with marginal rate of 7803%. However, the highest net benefits of Birr 414255 with least cost of production were obtained from the treatment combination Nafis and 244 kg ha^{-1} NPSB with marginal rate of 10986 %.

Based on these the most economically attractive combinations with low cost of production and higher benefits were treatment combination of Nafis with 244 kg ha^{-1} of NPSB fertilizer rate. Hence, this treatment combination appears to be sound for optimum onion production for small-scale farmers in the study area.

For growers who have full resources, the use of Nafis variety and application of 293 kg ha^{-1} NPSB fertilizer also profitable with higher cost of production and highest net benefit is recommended as a second option. However, as the experiment was done for only one season and single location, it has to be repeated over seasons and locations to make a conclusive recommendation.

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7. APPENDICES

Appendix Table 1.Mean squares from analysis of variance (ANOVA) for growth parameters

S0urce of variation	Degree of Freedom	Mean squares values			
		PH	LL	LN	DM
Replication	2	8.05^{ns}	7.41^{ns}	0.25^{ns}	60.81**
Varity	3	163.2**	15.32*	8.16**	343.97**
Fertilizer	3	825.33**	227.82**	83.68**	630.74*
Interaction	9	5.26^{ns}	10.17*	0.55*	10.41*
Error	30	13.99	4.10	0.24	4.55
CV (%)		7.06	4.6	4.59	2

ns =Non-significant at 5% probability level * and ** indicates significant and highly significant at 5% and 1% probability level, respectively

PH=plant height, LL= leaf length, LN=leaf number and DM=days to maturity of onion

Appendix Table 2.Mean squares from analysis of variance (ANOVA) for yield and yield related traits of onion

Source variation	Degree of Freedom	Mean squares values				
		BW	BD	MBY	UMBY	TBY
Replication	2	3.94^{ns}	0.152^{ns}	4.46*	0.01^{ns}	4.82*
Varity	3	448.25**	1.41**	44.10**	0.10**	40.25**
Fertilizer	3	5090.77**	12.62**	931.14**	0.83**	878.31**
Interaction	9	30.10*	0.28**	3.30**	0.01*	3.49**
Error	30	13.11	0.05	0.54	0.003	0.53
CV (%)		5.46	4.71	3.82	6.4	3.61

ns =Non significant at 5% probability level. * and ** indicates significant and highly significant at 5% and 1% probability level, respectively

BW= bulb weight, BD= bulb diameter, MBY =marketable bulb yield, UMBY= unmarketable bulb yield and TBY= total bulb yield of onion

Appendix Table 3. Land and seedling preparation

Appendix Table 4. Management practices under taken in the experimental field

Appendix Table 5. Harvesting and data collection