EFFECT OF BLENDED NPSB FERTILIZER RATES AND INTRA-ROW SPACING ON GROWTH AND YIELD OF ONION (*Allium cepa* L.) UNDER IRRIGATION CONDITION IN GURAGE ZONE, ETHIOPIA

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LIST OF ABBREVIATIONS AND ACRONYMS

ANOVA	Analysis of Variance
AVRDC	Asian Vegetable Research Development Center
CSA	Central Statistical Agency
DAP	Di-Ammonium Phosphate
EARO	Ethiopia Agricultural Research Organization
EIAR	Ethiopian Institute of Agricultural Research
FAOSTAT	Food and Agricultural Organization Statistics
HI	Harvesting Index
LSD	List Significant Difference
MARC	Melkassa Agricultural Research Center
MoA	Ministry of Agriculture
MoANR	Ministry of Agriculture and Natural Resources
MoARD	Ministry of Agriculture and Rural Development
MRR	Marginal Rate of Return
RCBD	Randomized Complete Block Design
SAS	Statistical Analysis System
SNNPR	Southern Nations, Nationalities and Peoples' Region
TSS	Total Soluble Solid

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ABSTRACT

The onion is one of Ethiopia's most important vegetable crops, and it is used virtually every day as a spice and vegetable in Ethiopian cuisine. However, its productivity is still low due to various limiting factors such as low soil fertility, improper plant density or spacing, disease and pests and lack of production technologies appropriate to different varieties and agro-ecological conditions. Haphard fertilizer application and intra row plant spacing are among others the most important once. To this effect, the present study was initiated to evaluate the effects of NPSB fertilizers and intra-row spacing on the growth and yield performance of onion variety of Bombay red under Enemor district conditions during the "irrigation" season. There were 12 treatment combinations which consisted of four levels of NPSB fertilizers (0, 122, 244 and 366kg ha^{-1}) and three levels of intra-row plant spacing (7.5cm, 10cm and 12.5cm). The experiment was laid out in Randomized Complete Block Design (RCBD) with factorial arrangement and under three replications. Results of the statistical analysis showed that the treatments had highly significant ($p \leq 0.01$) difference on the their interaction effect on both the growth and yield parameters tested (i.e. plant height, leaf number, bulb diameter, bulb length, weight of onion bulbs as well as marketable, unmarketable and total bulb yield). Generally, the treatment combination of 244kg ha^{-1} and 7.5cm intra-row spacing recorded the largest marketable bulb yield of 41.2t ha^{-1}, total bulb yield of (41.34t ha^{-1}), harvesting index of 77.17%, and the lowest unmarketable bulb yield of 0.14t ha^{-1}. Results of the correlation analysis also showed that almost all the tested parameters of onion were highly significantly and positively correlated with the marketable bulb yield of onion. Besides, as revealed by the partial budget analysis, the combined treatment of 244kg ha^{-1} NPSB and 7.5cm intra row spacing resulted in the highest net benefit increase of Birr 893,390 when compared with the other treatments combinations. Hence, the combined application of 244kg ha^{-1} of NPSB fertilizers and intra-row spacing 7.5cm is recommended for onion production in Enemor District as well as areas with similar agro-ecological conditions. However, since the study was conducted only for a single season and in only one location, further research is recommended to be carried out in more other locations as well as at different seasons.

Keywords: *Blended fertilizer, spacing, Bulb quality, Onion, yield*

1. INTRODUCTION

Onion (*Allium cepa* L.) is cross pollinated diploid 2n = 16, biennial plant originating from central Asia, i.e. Afghanistan, Iran, and Pakistan (Boukary *et al*., 2010). The plant belongs to the *Alliaceae* family (Hanelt, 1990). It is the genus *Allium's* most commonly grown species. The onion is among the major vegetable crop in the world, second only to the tomato in terms of economic importance. Onion has special nutritive value and therapeutic properties that have potential antibacterial, antifungal, anthelminthic, anti-inflammatory, antiseptic, antispasmodic, anti-cancer, anti-cholesterol and antioxidant properties (Telkamp, 2015 and Chand *et al.,* 2018). The crop grows in more than 261 countries, from those country world onion production in 2019 was about 99,968,016.00 tons of dry bulbs from 5,192,651.00 hectares of land with an average yield of 19.3t ha^{-1}. China is the biggest onion producer followed by other major onion producing countries India, USA, Iran, Egypt, Russia and Turkey (FAO, 2019). From Africa production in 2019 was about 13,903,222 ton of dry bulbs from 1,197,468 hectare of land with an average yield of 11.6 t ha^{-1}(FAO, 2019). Ethiopia, behind Egypt and South Africa, is the continent's third-largest onion producer, accounting for only 2.7 percent of global production between 2000 and 2011 (FAOSTAT, 2019).

As stated by CSA (2021), Onion area covered and production and productivity of onion in Ethiopia was 52, 616.24 hectares from which 4, 209, 670.43 tones were produced with an average yield of about 8.00t ha^{-1}. In Southern Nations, Nationalities and Peoples Region (SNNPR) the area covered by onion was 2, 244.42 ha and production was 16, 160.4 tones with the productivity of 7.2t ha^{-1} (CSA, 2021). Generally the productivity of onion in the SNNPR and Gurage Zone (study area) is less than the national.

Regardless of religion, race, or culture, the onion is one of Ethiopia's most important vegetable products, used practically every day as a spice and vegetable in local dishes (Anchala *et al*., 2006). Ethiopia is also favorable for the development of several onion types due to its highly diverse agro-climatic conditions (Lemma *et al*., 2006). It thrives primarily between the elevations of 700 and 2000 meters above sea level (Lemma, 2004). It is considered as a very important income crop for smallholder farmers, in addition to its culinary importance for practically every household. It's made all across the country for both domestic and export purposes (MoARD, 2005).

The productivity of onion in Ethiopia which, is far below the world average Yield. This lower productivity of onion in Ethiopia is attributed to various factors such as the use of largely low yielding local varieties and inappropriate or inadequate agronomic practices, including fertilizers and plant density per unit area. Such factors have uncontested impact on any crop productivity or yield and are known to vary from place to place according to the type of crop, environmental condition and soil fertility. Various studies indicate that, nitrogen (N) and phosphorus (P) are the primary macro nutrients, which are taken up in larger quantities from the soil system than the other essential nutrients (Marschner, 1995). Cognizant of this, the Minister of Agriculture (2015) had recommended a blanket application of 92kg ha^{-1} P_2O_5 and 105kg ha^{-1} N for the production of onion in Ethiopia, regardless of the type and fertility of the soil as well as variations in climatic conditions. In this regard, the Agriculture transformation Agency introduce NPSB fertilizer that contains N (18.7%), Phosphorous (37.7%) and Sulfur (6.95% and Boron (0.1) in the crop production system (EthioSIS, 2013).

Similarly, spacing is highly recognized to have a very significant effect on the productivity and quality of onion. Various research findings indicate that a wider spacing helps the individual plants to utilize more water, nutrients, air and light for their growth and development than those planted closer to each other (Devulkar, 2013). Hence, maintaining the optimum level of spacing or plant population is important to minimize competition the basic resources (water, nutrients, light, etc.) as well as to utilize the available cropland effectively and efficiently (Awase *et al.*, 2010). In line with this, EARO (2004), had generally recommended a double row spacing of 40cmx20cm x10cm (i.e. between furrows, rows and plants) for optimum production of onion in Ethiopia, again without considering the fertility status of the soil and variations in climatic conditions of the growing areas.

Conversely (Gebremeskel *et al*, 2015) studied that the tallest plant height was obtained at spacing of single planting 40 x 20x10 cm but, maximum total bulb yield and above ground dry biomass yield were obtained at the double planting of 40x20x5 cm in both years as compared to the other treatments. Similarly, other studies like that of Tegen *et al*. (2016) indicate that onion bulbs produced using the above stated intra-row spacing of 10cm are mostly bigger in size (>160g), which often are not preferred by consumers for home consumption. This shows that farmers all over the country, including those in Enemor district of the Gurage zone, are still using such blanket recommendations, without regards to the specific conditions prevailing in their respective localities. Cognizant of this, this

research was developed with studied and determined the optimum level of blended NPSB fertilizer and intra-row spacing for onion production under Enemor woreda (district) conditions of the Gurage zone, Southern Ethiopia.

1.1. Statement of the Problem

Onion is one of the major vegetable crops cultivated widely across Ethiopia, including the Enimor Woreda of the Gurage Zone. It is one of the major sources of income for smallholder farmers, in addition to its indispensable role for culinary purposes at every household level. However, its production, productivity and quality is often constrained by several biotic and abiotic factor, including improper agronomic practices like plant density per unit area and inappropriate application of the right type and rate of fertilizers (Eshetu *et al.*, 2006). As reported variously, smallholder farmers, including in the study area, are using different varieties from different sources, plant population (spacing) arrangements and haphazard application of fertilizer types and rates as provided to them as blanket recommendations by extension workers. This, however, is assumed to significantly affect its productivity and quality across the different areas on the basis of their variations in terms of soil and climatic endowments. It is therefore imperative to study and determine the right intra-row spacing and appropriate rate of the recently recommended blended NPSB fertilizer to the study area.

1.2. Research Questions

- What are the effects of the different intra-row arrangements (spacing) on the growth and yield performance of onion in the study area?
- What are the effects of the different rates of NPSB fertilizers on the growth and yield performance of onion in the study area?
- How would the interaction effect of the two factors as well as their respective levels influence the growth and yield performance of onion in the study area?

Hence, the present experiment was initiated and designed to be carried out in Enemor Woreda of the Gurage zone (Ethiopia) with the following prime objectives.

1.3. Research Objectives

1.3.1. General Objective

To study Effect of Blended NPSB Fertilizer Rate and Intra-row Spacing on Growth and Yield Performance of Onion (*Allium cepa* L.) in Gurage Zone, Ethiopia.

1.3.2. Specific Objectives

- To study and determine the optimum blended NPSB fertilizer Rate for onion production under Enemor woreda (district) conditions of the Gurage zone, Southern Ethiopia.
- To study and determine the optimum intra-row spacing for onion production under Enemor woreda (district) conditions of the Gurage zone, Southern Ethiopia.

2. LITERATURE REVIEW

2.1. Origin and Description of the Onion Plant

The onion (*Allium cepa* L.) is a belong of the *Alliaceae* family, which is said to have originated in southwestern Asia, the center of domestication and variability, from where it was originally distributed over the world and has been farmed as annuals for bulb production purposes for about 4700 years (Malik, 2000; Brewster, 2008; Saud *et al*., 2013). According to (Rabinowitch and Currah, 2002), the genus Allium contains over 750 species, with onion, Japanese bunching-onion, leek, and garlic were being the most important culinary *Allium* crops.

Onions were eaten mostly for their distinct flavor or for their capacity to improve the flavor of other dishes (Randle, 2000). The Onion stem is a flattened disc at the plant's base that grows below the soil surface. The shoot apex is located in the middle of the stem and is where all new leaves and roots are formed. A blade and a sheath make up each leaf. The leaf sheaths that appear to be the plant's stem above the soil level are actually pseudo stems. The leaf sheath covers the growth tip and forms a tube that encloses the youngest emerging leaves as it develops. Long, circular, and hollow leaves (Bosekeng, 2012).

Onion roots are shallow, usually occurring within 15-20cm of the soil surface and seldom extending more than 50cm horizontally (Brewster, 2008). Onion roots have a limited lifespan and are generated in large quantities. Roots rarely have branches or root hairs, and their width rarely increases (MoANR, 2011). The terminal inflorescences extend to 30 cm in height and grow from the ring like apical meristem scrapes. The flowers are tiny and form umbels at the stem's terminal tip (Norman, 1992). The umbel is a cluster of numerous blooms in varying stages of development, including between 2000-6000 little individual flowers. Flowering periods might span four weeks or longer. Six white petals, six stamens, and a three-carpel pistil characterize the flowers. Flowers contain nectar, which attracts pollinating insects such as honey bees. After anthesis, onion seeds mature approximately 45 days. The seeds are black, irregularly shaped, and tiny, weighing about 200 seeds per gram (Tindall, 1983).

2.2. Importance of Onion

Onions are farmed primarily for their bulbs and salad green shoots, and their use is not confined to any climate or nationality. It is the world's most adaptable vegetable and an

essential element in every kitchen as a condiment to flavor a wide range of cuisines. For various uses, the onion is one of the most significant vegetable crops in the world (Randle, 2000; Saud *et al*., 2013). As a result, onion is known as the "Queen of Kitchen" (FAOSTAT, 2017). In many developing nations, like Ethiopia, the crop serves a critical role in creating money and employment for rural communities, as well as contributing to the food security of millions of people (Boyhan *et al*., 2001).

Onion is processed into various products such as ketchup, chutney, sauce, puree, salsa, dry soup mixture and powder form as spice for seasoning in cooking (Bagali *et al.*, 2012). It is used as condiments for preparation of traditional foods commonly called *wot* in most Ethiopian cuisine. Bulbs and the lower section of the stem are the most popular as a seasoning or vegetable in stews (MoARD, 2005). It is also in therapeutic medicine in the country (Shiberu and Amin , 2014). Onion bulbs contain some important Vitamins (A, B and B2) and minerals (Ca, P, Fe, Cu and Zn), soluble sugars, small percentage of proteins, nicotinic acid. Therefore the crop has a range of health benefits including anti carcenogenic properties, anti platelet activity, anti thrombotic activity, asthmatic and antibiotic effects and effective against the common cold, heart disease, diabetes, osteoporosis, and other diseases (Decoteau, 2000; Griffiths *et al.,* 2002).

2.3. Soil and Climatic Requirements of Onion

With the rise of irrigated agriculture and a growing understanding of the sector's importance as a source of revenue, increased food security, raw material sources for businesses, and job opportunities, the sector is becoming more important. Vegetable production is becoming increasingly significant as it requires a huge labor force. Water harvesting systems for small farmers and irrigated agricultural growth projects have also aided the sector's development greatly. The success of production depends on the use of upgraded technology, such as cultivars with appropriate standards and high value in both domestic and international markets (Lemma *et al*., 2006).

Ethiopia has a lot of potential for growing onions all year, for both home and export usage. It grows best between 700 and 2000 meters above sea level (Lemma, 2003). The onion is rapidly gaining popularity among growers and customers alike. Its high yield potential, availability of suitable cultivars for potential utilization, ease of seed propagation, high domestic (bulb and seed) and market availability in both fresh and processed forms contribute to its appeal among producers (Lemma and Shimeles, 2003). Onions contribute

significantly to the national economy in addition to addressing local demands. With the country's increasing irrigated agriculture, there's a lot of potential for onion seed and dry bulb development across the country's various production belts.

The Ethiopian Agricultural Research Institute has made attempts to develop many improved onion cultivars, specifically for onion production and development. Farmers now have access to the cultivars Adama Red, Bombay Red, Red Creole, Melkam, Mermiru Brown, Nasik Red, and Nafis as a consequence of this effort (Lemma and Shimelis, 2003; MoARD, 2010). Throughout the year, small farmers and commercial growers produce it for local consumption and export. All parts of the onion plant are edible, though the bulbs are typically used as a flavour or a vegetable in a diversity of cuisines. Onions are appreciated for their pungent flavor and are used to flavor a variety of meals, including sauces, soups, sandwiches, and snacks like onion rings. Because of its great yield potential per unit area, availability of suitable cultivars for varied uses, and ease of seed propagation, it has surpassed the native shallot in popularity (Lemma, 2004) .

In Ethiopia, onions are one of the most important vegetable crops grown on a huge scale. It is also one of the most economically important veggies in the country. The area under onion is gradually rising, owing to its high profitability per unit area and ease of production, as well as the expansion of small-scale irrigation regions. During the "Meher" season, the crop is rain-fed, and during the off season, it is irrigated (CSA, 2018).

2.4. Onion Production and Challenges in Ethiopia

Despite the enormous benefits that onions provide to farmers, their output has been limited by a variety of biotic and abiotic phenomena, as well as institutional constraints. Disease and pest attacks, weeds, a lack of quality seed, a lack of pesticide, and a lack of irrigation water/pump for irrigation are all mentioned as key obstacles of onion production in the area by the majority of the sample producers. Pests and diseases, combined with a lack of improved agricultural technology, repeated droughts, and decreases in soil fertility levels, are some of the major contributors to Ethiopia's low and unstable crop yields, as shown in a survey conducted in the rift valley (the country's major onion-growing region) (Eshetu *et al.*, 2006).

According Muluneh (2019) vegetables are susceptible to a wide range of pests and diseases, and require intensive pest management. According to the research report, about 77.78 % of the respondent’s ranked insect attack is the most important production problem

followed by disease attack and lack of pesticide/poor management respectively. In addition to disease and pest problems, the results from the key informants and farmers' group discussions stress the critical importance of post-harvest losses which occur due to the perishable nature of onion and lack of appropriate post-harvest handling practices and processing technologies. The high incidence of insect pest and diseases infestation further accentuates high pre-harvest and post-harvest losses.

2.4.1. Plant Population Management

Improved agronomic management is a critical strategy for closing the production gap and increasing food security within a region and among agricultural households (Kihara *et al*., 2015). One of the key agronomic issues that can affect onion output and productivity in Ethiopia is plant population density (Yemane, 2013). Awas (2010) reported that at Adami Tulu, three onion cultivars, Bombay red, Adama red, and Nasika red, responded deferentially to intra-row spacing on yield and yield components. The prevalence of this competition among plants for the same resources, according to the two research findings, are due to the requirement for plants to achieve their maximum growth and development in order to achieve their potential yields. As a result, identifying this yield-limiting factor owing to population density is critical for onion production in the face of declining yield trends in the country. plant spacing has a major influence on plant growth and development of onions through competition for nutrients, moisture, air, radiation and other growth factors (Kantona *et al.*, 2003; Dereje, 2012). According to Khan *et al.* (2002) report maximum leaf per bulb was obtained from 12 cm spaced plants whereas 9 cm spaced plants gave 11.25 leaves per bulb. Nasir *et al.* (2007) also stated that the highest leaf number per plant was recorded at lower planting density.

Garlic leaves with the smallest leaf width (0.73cm) were found in higher plant density, (Seid *et al*., 2014). according to (Khan *et al*., 2003, Latif *et al*., 2010, and Sikder *et al*., 2010) Plant spacing of 10cm caused larger plant height, leaf length and number of leaves, bulb length, diameter, and weight of onion. Intra-row spacing of 10cm produced the largest bulb diameter (5.78 cm), followed by 8 cm and 6cm (Awas *et al*., 2010). According to Yemane *et al*. (2013), increasing intra-row spacing from 5 to 10cm increased onion bulb diameter and bulb neck from 4.66 to 5.63 cm and 1.48 to 1.74 cm, respectively. As the intra-row spacing increased from 5 to 10 cm, the percentage of large size bulbs increased from 9.3 to 20.3% (Yemane *et al.,* 2013).

According to Farage *et al.* (1992) report the higher bulb yield was obtained from plant spacing of 7 cm than with wider spacing treatments. Total bulb weight and mean bulb weights were significantly affected by plant spacing and 10cm plant spacing gave significantly higher bulb weight than 7.5 and 5cm (Fikreyohannes, 2005). Yemane *et al.* (2013) found highest total bulb yields at 5 and 7.5cm intra row spacing as compared to the 10cm intra-row spacing. Dereje *et al.* (2012) reported that individual plants, their components and total yield ha^{-1} were increased as plant density increased of shallot.

According to Awas *et al.* (2010) maximum marketable bulb yield (32.45 t ha^{-1}) of onion plants was obtained at 4 cm intra-row spacing followed at 6 cm (25.15 t ha^{-1}). Yemane *et al.* (2013) observed that as intra-row spacing increased from 5 to 10 cm, marketable bulb yield decreased from 34.49 to 28.1 t ha^{-1}. Significant differences were observed in marketable, unmarketable and total bulb yields per plots and 10 cm plant spacing gave significantly higher yields than plots with 20 cm spacing between plants in the rows (Sam-Aggrey *et al.,* 1986)

An increasing the intra row spacing from 5 to 10 cm, decreased marketable bulb yield from 34.49 to 28.10 t ha^{-1} (Yamane *et al.*, 2013). Seck and Baldeh (2009) reported that plant density has an impact on marketable bulb size where higher plant density increased the smaller marketable size. On the other hand the highest unmarketable bulb yields of onion and shallot are produced at narrower intra-row spacing (Dereje *et al.*,2012; Yemane *et al.*, 2013). According to Nasir *et al.* (2007) highest weights of small and medium sized bulbs of onion were obtained at higher population. However, the highest weights of large bulbs were found at the lowest planting spacing. Yield of medium bulbs increased with population but, the yield of large bulbs decreased as plant spacing increased (Rumpel *et al.*, 2000)

2.4.2. Fertilizer Management

Improved plant nutrient management is critical for healthy plant growth and development, particularly in the vegetative plant sections, in order to achieve optimal yields. The use of manure, compost, and/or inorganic fertilizer improves onion yields, which benefits growers (Zeleke and Derso, 2015). According to Assefa *et al.* (2015), utilizing the optimal amount of fertilizer nutrients significantly enhances onion bulb productivity when compared to using improved cultivars. Because onions are a heavy feeder vegetable crop, they require more mineral fertilizers for bulb and buildup than other vegetables (Yohannes

et al., 2013). According to Simon *et al.* (2015) report, three onion varieties (Adama Red, Bombe Red, and Nafis) have been tested at humbo, wolaita zone; Ethiopia was responded to different application of nitrogen and phosphorous fertilizer rates.

The findings revealed that as the levels of nitrogen and phosphorous were increased, the size and yield of onion bulbs increased, implying that optimal nutrient management has a positive contribution to onion yield improvement and productivity, particularly in areas where nutrient deficiency is critical. Yohanis *et al*. (2013) revealed a similar conclusion on the impacts of nitrogen and farmyard manure combination application, which increased onion bulb yield at Jimma environmental conditions. Furthermore, the effects of nitrogen and phosphorous on onion yield and yield components were researched on the vertisol of Shewa Robit, Northeast Ethiopia, where each rate of fertilizer was reacted to and recommendations were made based on the best yield obtained (Abdisa *et al*., 2011)**.** According to this research output, the application of nitrogen and phosphorus fertilizer showed a significant response on a fresh bulb yield, dry bulb yield, and total dry biomass and on harvesting index of onion as compared to the non-applied treatments.

In general, all of the outcomes of diverse nutrient management strategies have indicated that by using various plant nutrient management systems for certain soil types at specific locations, onion crop production and productivity may be optimized. Despite the fact that fertilizer rates should be determined depending on the soil type of the location, in most parts of the country, 200kg ha^{-1} DAP before transplanting by mixing with soil and 100kg/ha urea after 45 days after transplanting has been recommended as sufficient (Zeleke and Derso, 2015). In addition, the role of a moderate dose of sulfur was discovered to be responsive, with S up to 24kg ha^{-1} greatly improving bulb diameter and weight (Ahmed *et al.*, 1988).

2.5. Effect of NPSB Fertilizer on Yield and Yield Components of Onion

2.5.1. Effect of Nitrogen on Growth and Yield of Onion

Nitrogen (N) and phosphorus (P) are referred to as the primary macro nutrients because of the high likelihood of deficiency in plants and the massive amounts taken up from the soil in contrast to other key nutrients (Marschner, 1995). Many tropical African soils, particularly those rich in nitrogen (N) and phosphorus (P), are deficient in these essential plant nutrients (Richardson, 1968), which may be true of many Ethiopian soils as well (Murphy, 1959).

Nitrogen is a crucial component of plant proteins, enzymes, and vitamins. It is a crucial component of the photosynthetic molecule chlorophyll (Marschner, 1995). As a result, plants require far more nitrogen than most other nutrients, therefore it is critical to improve onion output both in quantity and quality (Kafkafi and Genbaum, 1971). The authors also noted that available nitrogen is often a more limiting factor for the plant growth than any other nutrients. As shallow rooted crop, onion is a heavy feeder of nutrients and require ample amount of nitrogen for optimum yield.

However, too much nitrogen might cause excessive vegetative growth, delaying maturity. Furthermore, excessive vegetative growth makes onion plants more susceptible to disease and lowers the dry matter content and storability of onion bulbs. As a result of the excess nitrogen, onion yields are lowered in both quantity and quality (Brewster, 1994; Srensen and Grevsen, 2001). On the other hand, when nitrogen levels are low, onion plants can become severely stunted, resulting in undersized bulbs and lower production. As a result, low levels of this nutrient in the soil have a negative impact on onion bulb quantity, quality, and storage. Onion bulb size is proportional to planting density, with smaller bulbs forming when plants are spaced closer together. Increased nitrogen fertilizer application is very required in these conditions to yield optimal-sized onion bulbs (Rice *et al*., 1993).

2.5.2. Effect of Phosphorus on Growth and Yield of Onion

Phosphorus is the second most critical nutrient for plant growth (Tisdale *et. al*., 1995). It accounts for 0.2 to 0.5 percent of the dry weight of the plant (Bieleski, 1973). Phosphorus is a component of membranes, chloroplasts, and mitochondria, as well as a component of sugar, and is known to have a role in several of physiological and biochemical processes in plants. In plant maturity, fruit setting, and seed formation, phosphorus was also important in energy transfer reactions and metabolic activities (Brady and Weil, 2002). In many tropical soils, phosphorus deficiency is one of the most significant restrictions to crop productivity. The reasons for all of this are either a low phosphorus content in the soil or a high phosphorous fixation rate (Fairhurst *et al*., 1999). As a result, most soils around the world are phosphorus deficient (Batjes 1997).

The use of phosphorous fertilizers is so frequently linked to an increase in the growth and development of crop plants, including onions. As Greenwood *et al*. (2001) found that applying phosphorous fertilizer to soils with a moderate phosphorus level improved onion growth and yield. Similarly, Singh *et al*. (1998) found that increasing P_2O_5 from 25 to

100kg ha-1 reduced onion weight loss, sprouting, and rotting after 160 days of storage. When soils are deficient in phosphorus, more phosphorous can be sprayed to enhance onion growth and output (Alt *et al*., 1999).

The presence of phosphorus in the soil encourages plant growth because phosphorus is a major building block of DNA molecules (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 has been recommended at rates of 33 to 80 $kg \cdot ha^{-1}$ (Sharma *et al.,* 2003). For instance, results of long term Phosphorus fertilizer trials on loamy sand soils in Germany have shown a strong response of onion to Phosphorus fertilization in the range of 0 to 52 $kg\ ha^{-1}$ (Alt *et al.,* 1999).

Many researchers are looking at the impact of phosphorus on plant growth (Nikolay *et al*., 1996; Warade *et al*., 1996; Hinsinger, 2001; Pant and Reddy, 2003 and Shafeek *et al*., 2004). Because phosphorus is an essential nutrient, they all agreed that its presence in the soil supports plant growth. Phosphorus fertilizer had a significant impact on onion plant output, resulting in a rise in overall bulb yield and its components. It could be linked to the effect of phosphorus on plant growth, which is shown in the production of bulbs. Many researchers had observed a similar pattern of outcomes (Gupta and Sharma *et al*., 2000, Shafeek *et al*., 2004). Furthermore, optimum growth and yield were achieved with a phosphorus application of $22kg\ ha^{-1}$, but even greater levels were effective with the variety Pusa White Flat, which had optimum growth and yield at $33kg\ ha^{-1}$ (Jha *et al*., 2000). Sulfur is also a necessary component for plant growth and development.

2.5.3. Effect of Sulfur on Growth and Yield of Onion

Sulfur, as a macro-nutrient, has a favorable impact on onion quality (El-Shafie and El-Gamaily, 2002; Bloem *et al*., 2004). It plays a role in the expression of bulb flavor strength, which is linked to onion pungency (propyl disulfides and other disulfides) and sugar content (glucose, fructose, and sucrose).

The onion is a sulfur-loving plant that requires a lot of it for optimum growth and improved output (Bloem *et al*., 2004). The enzyme allinase causes the volatile sulfur compounds in onions to be released when they are cut or damaged. Onion cultivars differ in the amount and types of sulfur compounds found in the bulb. Furthermore, sulfur is required for the formation of sulfur-containing amino acids (Anwar *et al*., 2001).

Sulfur has gotten a lot of attention in recent years when it comes to crop productivity all around the world. Sulfur in the soil has numerous impacts including lowering pH, enhancing the soil-water relationship and increasing the availability of nutrients such as P, Fe, Mn, and Zn (Marschner, 1998). According to Mengel and Kirkby (1982), plants absorb sulfur mostly in the form of sulfate, which has little competition for absorption with other elements. Onion sulfur needs vary depending on soil texture, leaching losses, sulfur concentration of irrigation water, previously applied fertilizer and sulfur-containing additions (Ahmed, *et al*., 1988). They found that applying sulfur at a rate of up to 24kg ha^{-1} enhanced the diameter and weight of onion bulbs significantly. They also stated that not applying sulfur to inadequate soils resulted in a low onion yield. Sulfur shortage causes stunted shoot growth, stiffened stems and woody and small-sized bulbs, as it is required for chlorophyll production. However, too much sulfur can make onions more pungent, which isn't ideal for the fresh market (Bloem *et al*., 2004).

2.5.4. Effect of Boron on Growth and Yield of Onion

Boron is an essential micro nutrient for plants, with the exception of molybdenum and copper, its requirements are lower than those of any other nutrients. It is the only non-metal among the micro nutrients, as well as the only micro nutrient that exists as a neutral rather than an ion over a wide pH range (Epstein and Bloom, 2005). Boron has been discovered to play an important role in the formation of anthers, pollen germination, and pollen tube expansion during reproductive activities (Loomis and Durst, 1992).

Boron deficiency can be confused with Ca deficiency, which also affects the growing points and leads to their „dying off.“ the primary role of boron is in the cell walls, where it provides cross-links between polysaccharides to give structure to cell walls (Egata *et al.*, 2021). Boron application directly affect yield and yield related attributes modifying the root development and facilitates nutrient-up take by initiating new root as well as stolen development which resulted in more tubers and bulb production (Egata *et al.*, 2021). Generally As Khalid (2019) reveled application of micro nutrient have a significant improvement on onion yield at a rate of zinc sulfate (ZnSO4 at 0.5%), iron sulfate (FeSO4 at 1.0%), and boron (B at 0.5%).

2.6. Response of Onion to Interaction Effect of NPSB Fertilizer Rate and Intra-Row Spacing

NPSB fertilizer rate and intra-row spacing were used to control onion growth and yield parameters such as plant height and number of leaves, length, diameter, and weight of onion bulbs, and bulb yield. Using 150kg ha^{-1} NPS fertilizer on plants spaced 10cm intra-row spacing resulted in the maximum plant height (67.74cm), bulb width (7.01cm), bulb length (5.85cm), bulb weight (139.05g), marketable (41.58t ha^{-1}) and complete bulb yields (42.04t ha^{-1}) (Amakel, 2020). This treatment increased marketable bulb production by 78.72 percent as compared to marketable bulb output reported from vegetation without NPS fertilizer cultivated at 5cm intra-row spacing.

Similarly Nibret (2020) also reported that Garlic yields of 15.88t ha^{-1} and 15.5t ha^{-1}, respectively, were obtained when garlic plants were given 242kg ha^{-1} NPS fertilizer and when garlic plants were planted at 15cm intra-row spacing. Similarly, when garlic plants were given 242kg ha^{-1} NPS fertilizer and intra-row spacing of 5cm with a fee of 28.01 t ha^{-1}, the best total yield of 23.16t ha^{-1} was obtained. Furthermore, garlic plant life was inferior in all evaluated parameters of garlic except above ground biomass, bulb weight, clove variety, and marketable yield, with the exception of NPS fertilizer. Furthermore, plants spaced at 5cm intra-row spacing performed poorly in all metrics tested, resulting in excessive unmarketable production and complete yield.

Pervez *et al*. (2004) also found that the treatment combination of 150kg ha^{-1} N and 15cm intra-row spacing resulted in the largest number of leaves per plant. According to the authors, the highest total biomass per plant was obtained when 200kg ha^{-1} nitrogen was combined with 15cm intra-row spacing, followed by 200kg ha^{-1} nitrogen and 10cm spacing. According to Weldemariam *et al*. (2015), the combination of 100kg ha^{-1} nitrogen and 15cm intra-row spacing increased onion bulb output (40.83t ha^{-1}). However, increasing the nitrogen level to 150kg ha^{-1} did not result in a significant increase in bulb yield.

3. MATERIALS AND METHODS

3.1. Description of the Study Area

The experiment was conducted under field condition in Enemor district of the Gurage zone. It was carried out under irrigation condition in 2021. The site located 192km away from Addis Abeba and 42km from city administration. Enemor district is located at 8°0′ N latitude and 37°49′ E longitude. The altitude of the Woreda is 1876m a.s.l. Clay loamy and Vertisol soil types are the most dominant ones in the area (Elias, 2017). It has bimodal rainfall pattern with the short rainy season falling from February to May and the long rainy season from June to September. The mean annual rainfall is 1150mm and the minimum and maximum air temperatures are 17°C and 21°C respectively (Elias, 2017).

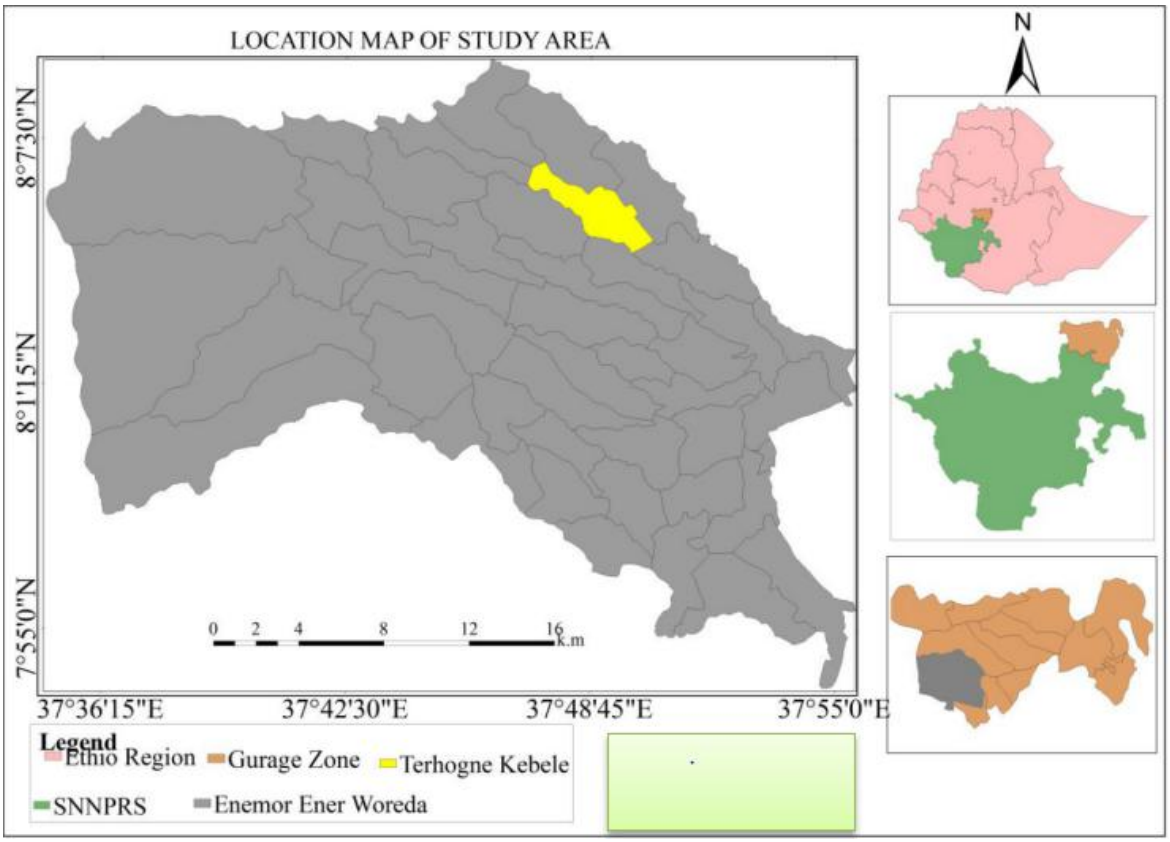


Figure 1. Map of the study area

3.2. Experimental Materials

Bombay Red variety of onion was used as a test crop, which was collected Melkasa Agricultural Research (MARC).The variety is registered by Melkasa Agricultural Research Center (EARO, 2004). It is an early maturing variety, takes less than 120 days to maturity (EARO, 2004). it also preferred by smallholder farmers and commercial farmers throughout the country(Dasash, 2019).

Three rate of blended NPSB fertilizer 122kg ha^{-1}, 244kg ha^{-1} and 366kg ha^{-1} and 150kg ha^{-1} of urea were used.

Table 1. The actual content of blended NPSB fertilizer rate within the ratio

NPSB(kg/ha)	N (%)	P_2O_5 (%)	S (%)	B (%)
122	22.8	46	8.5	0.1
244	45.6	92	17	0.2
366	68.44	138	25.4	0.4

Hint: *100kg N:P2O5:S:B, the concentration was 18.7%, 37.7%, 6.95% and 0.1% respectively*

3.3. Experimental Treatments and Design

The experimental treatments were: (1)Three intra-row spacing (7.5cm, 10cm and 12.5cm), which were considered as per recommendation by EARO (2004), and (2) Blended NPSB fertilizers (122kg ha^{-1}, 244kg ha^{-1} and 366kg ha^{-1} and without NPSB or control), which were 50% below and above the blanket recommendation by MoA (2015), i.e. 92kg ha^{-1} P_2O_5 or when changed into N:P_2O_5:S:B, the concentration was 18.7%, 37.7%, 6.95% and 0.1% respectively. The experiment was laid out in a Randomized Complete Block Design (RCBD) with factorial arrangement in three replications. As such, the experiment had a total of 12 treatments combinations and 36 experimental units or plots.

3. 4. Experimental Procedure

Good quality seeds of Bombay red variety of onion was sown in rows on 1m x 5m well prepared seedbed at seeding rate of 3-4kg ha^{-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 as described by EIAR (2007). The experimental site was prepared well by broken down large clods in order to make the fine tilt of the experimental plots. The whole field was divided in to three blocks containing twelve (12) treatments. The plots were be leveled and prepared with a distance of 0.5m between plots, 1m between blocks.

The total size of the experimental area and net area were 281.8m^2 ·The size of each experimental plot and net area was 2 x 1.5m (3m^2) and 1.6 x 1.5m (2.4$m^{2)}$ respectively. After 45 days of seeding, only healthy, vigorous and uniform-sized seedlings were

transplanted to the experimental field, which was laid out with double row planting system at the spacing of 40cm x 20cm between irrigation furrows (double rows) and intra-raw spacing of 7.5cm, 10cm and 12.5cm respectively.

The total amount of NPSB and 50kg of urea was applied after the establishment of onion seedlings (ten days after transplanting). The other 50kg of urea was applied as side dressing 45 days after transplanting while the remaining 50kg was applied at the establishment of bulb, 60 days after transplanting (EIAR, 2007). Experimental units were irrigated using hand irrigation method by water can in each plot and row in plots to prevent mixing of fertilizer rates agreed to different plots. Transplanted seedlings were irrigated using furrow irrigation at 4-5 days interval until their establishment and at 5-7 days intervals until maturity. Fifteen days before harvesting however, irrigation of plants were stopped for curing purpose as recommended by Nikus (2010).

3.5. Data Collection

Data was collected on the following yield and yield components. Ten randomly selected plants from the middle rows of each experimental plot was tagged and used for data recording. The detailed methodology adopted for data collection is presented as follows.

3.5.1. Growth Parameters

Average 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 standard ruler. This was measured when the plats attain a full physiologically matured stage.

Average Leaf Length (cm): The longest leaves of ten randomly selected plants were measured at full physiologically matured stage using a standard ruler.

Leaf Number: Number of leaves of ten randomly selected plants per plot were counted at physiologically matured stage and thereby the mean values were computed.

Leaf Dry Weight (g): Dry weight of ten randomly selected above ground part of plants at harvest was measured using sensitive balance after drying them in oven for 24 hours at 640C and the mean values per plant was computed and used for further analysis.

3.5.2. Yield Parameters

Average Bulb Weight (g): The mean bulb weight of ten randomly selected bulbs at harvest were measured with sensitive balance and used for further analysis (Guesh Tekle, 2015).

Average Bulb Length (cm): The average length of ten randomly selected bulbs per plot were considered by measuring from the bottom to the top of the Bulb using a standard caliper (Guesh Tekle, 2015).

Average Bulb Diameter (cm): The mean size of the harvested bulbs were computed by measuring the diameter of ten randomly selected bulbs from each plot using a standard caliper (Lemma and Shimeles, 2003).

Bulb Dry Weight (g): Ten randomly selected bulbs were taken from each plot and chopped into small 1-2cm cubes. The exact weight of each sample was determined and recorded as fresh weight. Each sample was placed in a paper bag and put in an oven until constant dry weight was attained. Each sample was then immediately weighed and recorded as dry weight yield.

Total Dry Biomass (g): This was determined by summation of the shoot and bulb dry weights of sample plants.

Total Marketable Bulb Yield (t ha^{-1}): Harvested bulbs which are free of mechanical, disease and insect pest damages as well as uniform in color and medium to large in size (20g-160g) were considered as marketable. The weight of such bulbs were taken from those harvested within the net plot areas (Lemma and Shimeles, 2003).

Total Unmarketable Bulb Yield (t ha^{-1}): Harvested bulbs that are under and oversized (i.e. <20g and >160g), misshaped, decayed, discolored, diseased and physiologically disordered were considered as unmarketable (Lemma and Shimeles, 2003). The weight of such bulbs were considered from those within the net plot areas.

Total Bulb Yield (t ha^{-1}) the total yield was calculated by summing up both the marketable and unmarketable yields of the bulbs (Guesh Tekle, 2015).

Harvesting Index (%): This was expressed as the ratio of total bulb dry weight to the total biomass dry weight and were expressed in percentage.

$$\text{Harvesting Index} = \left(\frac{\text{Bulb Dry Weight}}{\text{Total Dry Biomass}}\right) \times 100$$

3.6. Correlation Analysis

Correlation coefficient was calculated for the different response variables which help to show how the yield components and growth characters affecting the marketable bulb yield of onion.

3.7. Data Analysis

All collected data were subjected to Analysis of Variance (ANOVA) using SAS (Statistical Analysis System) software, version 9.3 (SAS, 2014). Mean separation was carried out using Duncan Multiple Range Test (DMRT) at 5% level of significance (Gomez, 1984).

3.8. Partial Budget Analysis

Partial budgeting is a way for organizing and storing experimental data and information about the costs and benefits of various treatment options. According to CIMMYT (1988) The partial budget analysis comprises the total variable costs and net benefits of each treatment. The net benefit of the treatments was estimated by removing variable costs from the gross benefit of each treatment. As a result, the following procedure had been used to calculate it.

Gross Unadjusted Bulb Yield (kg ha^{-1}): it was the average yield of marketable bulb Weight ha^{-1}.

Adjusted Bub Yield (kg ha^{-1}): It was the average yield adjusted downward by a 10% To reflect the difference between the experimental yield and yield of farmers.

Gross Income/Benefit (ETB ha^{-1}): It was computed by multiplying field/farm gate Price that farmers receive for the crop when they sale it as adjusted yield.

Total Cost (ETB ha^{-1}): It Were assumed the cost of labor for transplanting, applied of fertilizer, costs of seed and fertilizer among treatments.

Net-Benefit (ETB ha^{-1}): It was calculated by subtracting the total costs from gross Income/benefits.

Marginal Rate of Return (%): It was calculated by dividing change in benefit by Change in cost.

4. RESULTS AND DESCUSSION

4.1. Physico-chemical Properties of the Experimental Site Soil

Initial soil samples were collected from the experimental field before planting. A random soil samples were collected in zigzag manner from >30 different points from a depth of 15-200cm (surface soil) using auger and composited to make one homogenized sample. The soil samples were air dried, grinded, and mixed thoroughly before laboratory analysis. The air dried soil was sieved through 2mm mesh and soil physico-chemical parameters for this study was analyzed at Wolkite and Hawassa soil laboratory. The composite soil sample was analyzed for selected physico-Chemical properties mainly textural analysis (sand, silt and clay), soil pH, total nitrogen, available phosphorus, Available of Sulphur, Available of Boron, Electric conductivity and organic carbon (Table 1) using standard laboratory procedures at soil laboratory of Wolkite And Hawassa. Soil texture analysis was performed by Bouyoucous hydrometer method (Day, 1965).

Total N was analyzed using the Kjeldahl digestion, distillation and titration method as described by Black *et al.* (1965) by oxidizing the OM in concentrated sulfuric acid solution (0.1N H2SO4). The pH of the soil was determined on 1:2.5 (weight/volume) soil samples to water ratio using a pH meter (Motsara and Roy, 2008). Available phosphorus was determined by using procedures of Olsen methods in soils by Extracting with Sodium Bicarbonate (Olsen, 1954). Boron was extracted by hot water & measured by azomethine-H colorimetric method (Bingham, 1982) and available Sulfur was measured with 0.01M Ca $(H2P04)_2$, they were analyzed as described by Lisle *et al.* (1994) (Table 2).

Table 2. Major soil characteristics of the experimental site (taken before planting)

Soil Variable	Unit	Value	Remark	Reference
pH	soil: water	6.8	Slightly Acidic	(Hazelton and Murphy, 2007)
Organic carbon content	%	1.404	Low	(Tekalign Tadesse, 1991)
Total Nitrogen	%	0.12	very Low	(Tekalign Tadesse, 1991)
Available Phosphorus	Ppm	4.68	Low	(Hazelton and Murphy, 2007)
Available of Sulphur	Ppm	17.83	Low	(Lisle *et al.* 1994)
Available of Boron	Ppm	0.084	Low	(Bingham, 1982)
Electrical Conductivity	ms	63.25	Non-saline	
Sand (%)	%	20		(Day, 1965)
Silt (%)	%	46		
Clay (%)	%	34		
Textural class			Silty clay	

4.2. Growth Parameters of Onion.

4.2.1. Plant Height (cm)

The main effects of blended NPSB fertilizer and intra-row spacing as well as their interaction effects highly significantly ($P \leq 0.01$) influenced the plant height of onion (Appendix 1). Application of different rates of NPSB fertilizer rate and intra-row spacing increased plant height of onion due to the presence of macro and micro nutrients and less computation of growth factors.The longest plant height (66.97cm) was recorded by the interaction of 366kg ha^{-1} NPSB fertilizer rate and 12.5cm intra-row spacing. On the other hand, the shortest plant height (34.35cm) was recorded from plants grown without fertilizer at 7.5cm intra-row spacing (Table 3).

The reasons for excessive in length of plants observed in high level of NPSB and the widest intra-row spacing in the present study could be count of the fact that able supply of nitrogen advance the formation of chlorophyll which is contribute to higher photosynthetic activity, vigorous vegetative growth and taller plants. Furthermore, nitrogen is a crucial component of amino acids and the production of proteins, both of which are necessary for plant growth (Bungard *et al*., 1999). In shoot and root tips, where metabolism is intense and cell division is rapid, considerable amounts of phosphorus are necessary (Ndakidemi and Dakora, 2007). Similarly, Sulphur is a vital ingredient for plant growth, accumulating 0.2 to 0.5 percent of dry matter in plant tissue (Kumar and Singh, 1992). Boron treatments also have a substantial impact on the crop's plant height. According to Manna (2014), the treatment of 0.5 percent Boron, considerably increased plant height over the control.

On the other hand Plant spacing has also major influence on plant growth and development of onions through competition for nutrients, moisture, air, radiation and other growth factors (Kantona *et al.*, 2003; Dereje, 2012).Wider plant spacing promotes plant growth due to less competition for light and nutrients.

4.2.2. Leaf Number Per Plant

The main effects of blended NPSB fertilizer and intra-row spacing as well as their interaction effects highly significantly ($P \leq 0.01$) influenced the Leaf number per plant of onion (Appendix 1). The maximum Leaf number per plant (9.2) was recorded by the interaction of 244kg ha^{-1} NPSB fertilizer rate and 12.5cm intra-row spacing. On the other hand, the minimum leaf number per plant (3.7) was recorded from plants grown without fertilizer at 7.5cm intra-row spacing (Table 3).

The availability of enough plant nutrients through the application of NPSB fertilizer, which favorably influenced the vegetative growth of the plants, could be the reason for the observed greatest number of leaves per plant. The synthesis of several protein components essential for leaf development, photosynthesis, and metabolic processes required for plant growth were among the nutrients. By expanding the photosynthetic area, phosphorus and nitrogen have been linked to the formation of additional leaves.

The findings of Blay *et al*. (2002) and Gebremichael *et al*. (2017), who discovered that nitrogen supply enhanced the number of leaves per plant, are consistent with the current study. When low amounts of phosphorus fertilizer are given, garlic leaf expansion and leaf surface area, as well as the number of leaves, are reduced (Uzma *et al*., 2016). Similarly, 30kg S ha^{-1} and 69 kg P_2O_5. Plants planted at 12cm intra-row spacing generated the most leaves per bulb (Khan *et al*., 2002), which is consistent with the current study.

Table 3. Interaction effects of blended NPSB fertilizer and intra row spacing on selected growth parameters of onion

NPSB fertilizer (kg ha^{-1})	Intra row spacing (cm)	PH (cm)	LN/plant
0	7.5	35.23^{g}	3.7^{c}
	10	46.27^{def}	3.4^{c}
	12.5	41.77^{gf}	8.5^{a}
122	7.5	42.17^{gf}	6.7^{b}
	10	53.17^{cd}	7.0^{ab}
	12.5	58.2^{cb}	8.1^{ab}
244	7.5	45.07^{ef}	9.2^{a}
	10	53.07^{cd}	8.3^{ab}
	12.5	63.27^{ab}	9.23^{a}
366	7.5	40.10^{gf}	8.2^{ab}
	10	50.00^{de}	7.4^{ab}
	12.5	66.97^{a}	9.0^{a}
SE±		1.86	0.45
CV (%)		7.9	13.1

Where: *PH = Plant Height; LN = Leaf Number; SE = Standard Error; and CV = Coefficient of Variation. Means with the same letter (s) within a column are not significantly different at 5% ($p \leq 0.05$) level of significance.*

4.2.3. Leaf Length (cm)

The analysis of variance (ANOVA) revealed that leaf length was highly significantly ($P \leq 0.01$) influenced by the main effects of NPSB fertilizer rate and intra-row spacing (Appendix 1). However, their interactions did not show significant difference in the leaf length ($P>0.05$). The longest leaf length (41.9cm) was recorded by the application of 366kg ha^{-1} NPSB fertilizer. The shortest leaf length (31.5cm) was recorded from plants without NPSB fertilizer (Figure 2). On the other hand, the longest leaf length (42.4cm) was obtained from plants spaced at 12.5cm intra-row spacing. While the shortest leaf length (34cm) was recorded from plants spaced at 7.5cm intra-row spacing (Figure 3).

In the current study, a high level of NPSB fertilizer and the largest intra-row spacing improved leaf length. Nitrogen is a component of several essential cell components and is essential for plant elongation (Fageria and Baligar, 2008; Marschner, 1995). These findings are consistent with those of other researchers who found that applying nitrogen from mineral fertilizer sources (as a single or blended form) considerably increased the

length of onion leaves due to its role in the synthesis of chlorophyll, enzymes, and proteins (Jilani *et al*., 2010; Abdissa Yohannes *et al*., 2011; Rao *et al*., 2013, Birhanu Messele, 2016; Gebremichael *et al*., 2017). According to Abdulsalam and Hamaiel (2004), increasing phosphorus fertilizer rates up to 92kg ha^{-1} improved plant height and leaf length, which is consistent with the findings of this study. In addition, Fatma *et al*. (2014) discovered that using a sulfur-holding fertilizer had a beneficial effect on all onion growth indicators.

On the other hand, spacing has its own influence because wider spacing results in less competition for light, but closer spacing results in more competition. Similarly, Jilani *et al*. (2010) found that larger intra-row spacing enhanced onion leaf length considerably. Jilani and Ghaffor (2003) also suggested that plant densities could alter length of leaves. Khan *et al*. (2003), and Khan *et al.* (2002) also reported that wider intra-row spacing significantly increased leaf length of onion.

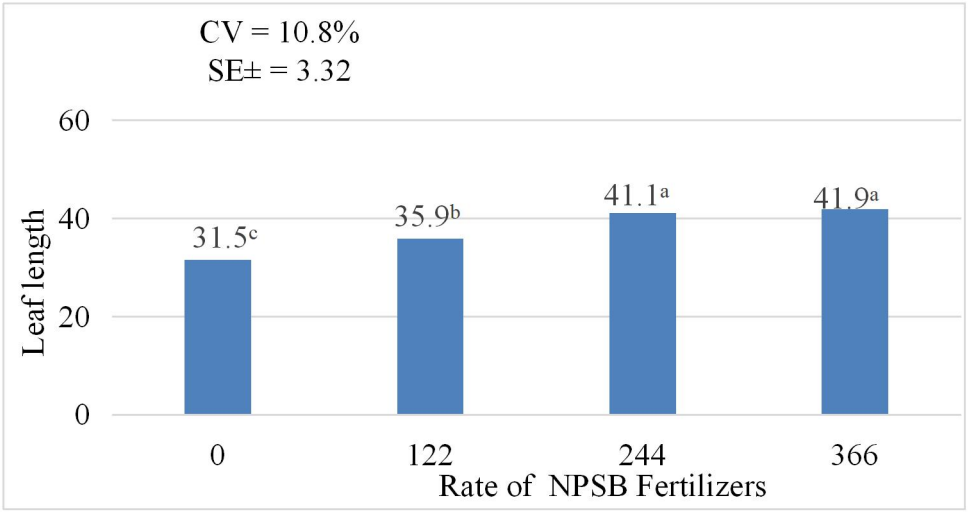


Figure 2. Main effect of NPSB Fertilizer rate on leaf length of onion

Where: *CV = Coefficient of Variation;* SE = *Standard Error;*

Means with the same letter (s) within a bar are not significantly different each other at 5% ($p \leq 0.05$) level of significance.

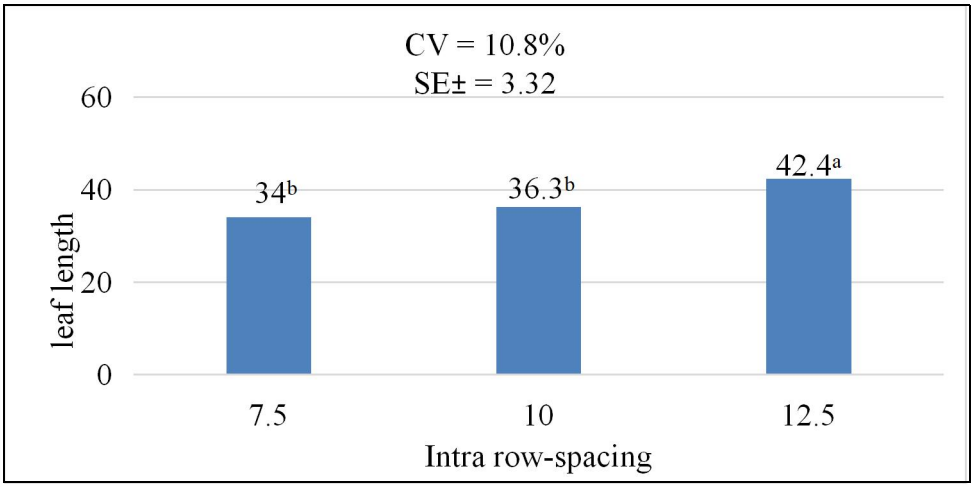


Figure 3. Main effect intra-raw spacing on leaf length of onion.

Where: *CV = Coefficient of Variation; and SE± = Standard Error;*

Means with the same letter (s) within a bar are not significantly different each other at 5% (p≤0.05) level of significance.

4.2.4. Leaf Dry Weight (g)

The analysis of variance (ANOVA) indicate that leaf dry weight was highly significantly ($P \leq 0.01$) influenced by the main effects of NPSB fertilizer rate (Appendix Table 1). However, intra-row spacing and their interactions did not show significant difference in the leaf dry weight ($P>0.05$). The maximum leaf dry weight (10.8g) was recorded by the application of 366kg ha^{-1} NPSB fertilizer. The minimum leaf dry weight(6.5g) was recorded from plants without NPSB fertilizer (Figure 4).

The results of this study clearly showed that the incorporation of nitrogen, phosphorus Sulphur and Boron fertilizers an effect on promoting vigorous plant growth. Also the improvement of fresh and dry weight of whole onion plant could be attributed to an increased photosynthetic area in response to NPSB fertilization that enhanced assimilates production and partitioning to the plants. The obtained results are in conformity with the findings of Shege, 2015, Abrheham *et al*. (2014) ; Balasubramonium *et al*. (1979) Betewulign *et al*. (2014); faraooqui *et al*. (2009) and Zaman *et al*. (2011) on garlic which said that NPS fertilization positively affected all vegetative characters of garlic plant.

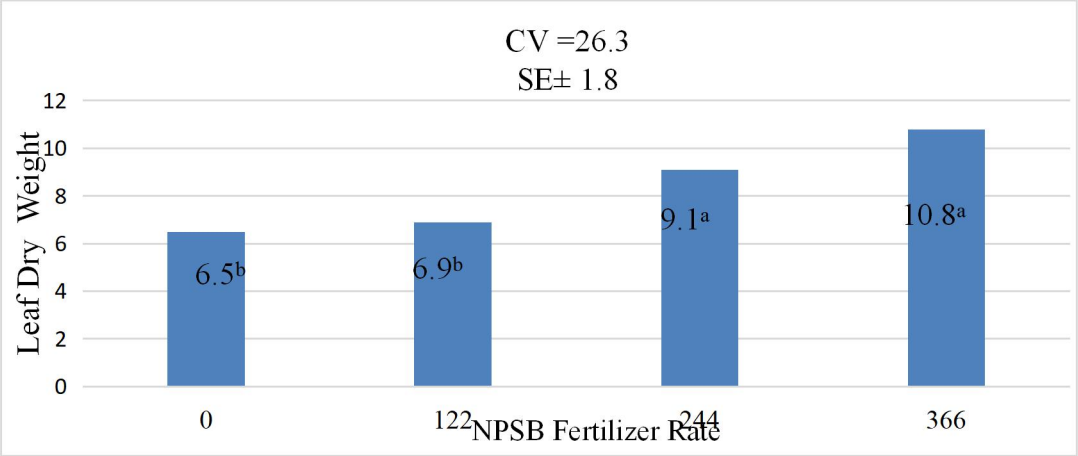


Figure 4. Main effect of NPSB Fertilizer rate on leaf dry weight of onion.

Where: *CV = Coefficient of Variation; and SE± = Standard Error;*

Means with the same letter (s) within a bar are not significantly different each other at 5% ($p \leq 0.05$) level of significance.

4.3. Yield Components and Yield of Onion

4.3.1. Fresh Bulb Weight(g)

The analysis of variance showed that NPSB fertilizer rate and intra-row spacing as well as their interaction effects highly significantly ($P \leq 0.01$) influenced the average bulb weight of onion (Appendix 2).The largest mean bulb weight 75.75g was obtained from the application of 244kg ha^{-1} NPSB fertilizer on 12.5cm spaced onion plant. On the other hand, the smallest average bulb weight (18.77g) was recorded from plants grown without NPSB fertilizer and spaced at 7.5cm intra-row spacing(Table 4).

Largest bulbs with highest average weight were produced with highest NPSB fertilizer rates and widest intra-row spacing, which could be linked to a suitable supply of plant nutrients for onion plant growth and development. The plant's metabolic activities enhance as a result of these conditions, resulting in increased assimilate accumulation and translocation from leaves to bulbs.

The findings of this study are similar to those of (Amakel, 2020), who found that higher bulb weight was related to higher NPS and broader intra-row spacing. Furthermore, applying NPKS or single nutrients such as phosphorus and sulphur increased onion bulb weights (Kumar and Singh, 1992; Baiyeri, 2002; Aliyu's *et al*., 2008; Aster, 2009; Mahala, 2015). Muluneh (2016) found that when nitrogen levels were higher and intra-row spacing

was substantially wider, bulb weight was highest, similar to Naik and Hosamani's findings (2003). Aliyu *et al*. (2008) discovered that densely populated onion plants produced smaller bulbs than sparsely populated onion plants, which is similar to the current study's findings.

4.3.2. Bulb Diameter (cm)

The main effects of NPSB blended fertilizer, intra row spacing and their interaction highly significantly ($P \leq 0.01$) influenced bulb diameter of onion (Appendix 2). The widest bulb diameter (6.8cm) was recorded by the combined treatment of 244kg ha^{-1} NPSB fertilizer and 12.5cm intra-row spacing. Plants grown at 7.5cm intra-row spacing without NPSB fertilizer produced bulbs with narrow bulb diameter (3.1cm) as indicated in Table 4.

The probable reasons for wider bulb diameter of onion recorded from plants supplied with relatively high NPSB and at wider intra-row spacing could be due to the presence of enough nutrients (N, P S and B) that promote the growth and development of plants and consequently the diameters of bulbs. The increase in bulb diameter is obviously associated with increased in dry matter production and allocation of assimilates to the bulb through increased number of leaves, plant height and leaf length and thus higher photo assimilate concentration in the bulbs that ensure large bulb diameter.

According to Abraha *et al*. (2015) and Uzma *et al*. (2016), the combined application of phosphorus and sulfur increased the diameter of garlic and onion, which is consistent with the findings of this study. When onion plants were planted at considerably wider intra-row spacing, many studies noticed bigger onion bulbs with broader diameter, similar to the current study (Akoun, 2005; Jilani *et al*., 2009; Geremew *et al*., 2010, Muhammad *et al.*, 2011; Yemane *et al*., 2013).

4.3.3. Average Bulb Length (cm)

Bulb length of onion was very highly significantly ($P \leq 0.01$) influenced by the main effects of blended NPSB fertilizer rate, intra-row spacing as well as their interaction (Appendix 2). The longest bulb length 5.6cm was recorded with the treatment combination of 244kg ha^{-1} NPSB fertilizer rate and 12.5cm intra-row spacing. The shortest bulb length 3.3cm of onion was recorded from plants spaced at 7.5cm intra-row spacing and grown without NPSB fertilizer (Table 4).

The availability of enough plant nutrients through the application of NPSB fertilizer, which positively influenced cell enlargements, rapid root development, and good water utilization, which in turn promote plant growth and thus onion bulb length, could be one of the reasons for the observed longest bulb length. Onion bulb lengths were considerably longer in all fertilized plots than in the unfertilized plot.

These findings are consistent with those of Falodun *et al*. (2013), who found that NPK treatment resulted in the longest bulb length (80kg ha^{-1}). Kumar *et al*. (2017) also found that applying the recommended dose of NPK fertilizers after harvesting resulted in the longest bulb length. In reaction to nitrogen fertilizers, Yadav *et al*. (2003) and Reddy (2005) showed an increase in onion bulb length. According to Dawar *et al*. (2007), high planting density results in shorter bulb length due to the high computation of soil nutrients, water, and light, which causes bulb size to be reduced in order to reach its full potential.

Table 4.Interaction effect of NPSB blended fertilizer rate and intra-row spacing on yield component parameters of onion.

NPB fertilizer (kg ha^{-1})	Intra-row (cm)	FBW(gm)	BD (cm)	BL(cm)
0	7.5	18.77^{e}	3.1^{h}	3.3^{f}
	10	38.8^{d}	3.83^{g}	3.4^{f}
	12.5	65.1^{b}	4.67^{de}	4.3^{cd}
122	7.5	28.8^{de}	4.2^{f}	3.5^{f}
	10	49.3^{c}	4.5^{ef}	4.1^{e}
	12.5	63.7^{b}	5.9^{c}	4.8^{bc}
244	7.5	49.97^{c}	4.8^{de}	4.0^{e}
	10	73.4^{ab}	4.9^{d}	4.7^{cd}
	12.5	75.73^{a}	6.8^{a}	5.6^{a}
366	7.5	63.67^{b}	5.6^{c}	4.93^{bc}
	10	75.47^{a}	5.6^{c}	5.3^{ab}
	12.5	72.9^{ab}	6.3^{a}	5.27^{ab}
SE±		2.88	0.19	0.39
CV (%)		10.9	3.7	6.3

Where: *FBW =Fresh Bulb Weight; BD = Bulb Diameter; BL = Bulb Length;* SE± = *Standard Error; and CV = Coefficient of Variation*

Means with the same letter (s) within a column are not significantly different each other at 5% ($p \leq 0.05$) level of significance.

4.3.4. Bulb Dry Weight (g)

The bulb dry weight of onion was highly significantly ($P \leq 0.01$) influenced by effects of NPSB fertilizer and intra-row plant spacing. However, their interactions did not show significant difference in the Bulb dry weight ($P>0.05$) (Appendix 3). The highest bulb dry weight (24.8g) was recorded by the application of 366kg ha^{-1} NPSB fertilizer. The lowest Bulb dry weight (11.9g) was recorded from plants without NPSB fertilizer (Figure 5). On the hand the effects of intra-row spacing was highly significantly ($p \leq 0.01$) influenced average dry biomass yield. As intra-row spacing increased from 7.5 to 12.5cm average dry biomass yield was also increased from 16.4g to 20.5g (Figure 6).

The higher bulb dry weight from each level of blended NPSB fertilizer is most likely owing to the availability of sufficient nutrients with low competition among plants, resulting in superior photosynthetic accumulation in their sink (bulbs) than the control. Higher levels of photosynthates in the bulbs could result in larger individual bulb weights, bulb diameters, and neck diameters. Because phosphorus is a large component of nucleic acid, which aids in the growth and development of the entire plant, more energy is stored in the bulb.

The results of the present study are in agreement with findings of other researchers who report that an increased in mean fresh bulb weight in response to nitrogen application could be attributed to increase in number of leaves, leaf length and extended physiological maturity that led to increased assimilate production and allocation to the bulbs (Kokebe *et al.,* 2013). Higher nitrogen doses resulted in higher bulb dry matter yields than lower nitrogen doses (Yadav *et al.*, 2003) and El-Tantawy and El-Beik (2009). The use of sulfur-containing fertilizers resulted in a high utilization of macro and micro-nutrients, resulting in a considerable increase in total solids in onion bulbs at maturity (Nasreen *et al*., 2007).

Increased nitrogen application resulted in considerable increases in bulb weight Abdissa e*t al*. (2011). Abraha *et al*. (2015) also found a beneficial effect of N, P, S, and Zn fertilizer application on onion bulb growth, which contributes to bulb weight. On the other hand These finding is consistent with those of Dereje *et al*. (2012) and Sikder *et al*. (2010), who found that wider spacing resulted in increased bulb dry weight in shallot and onion, respectively.

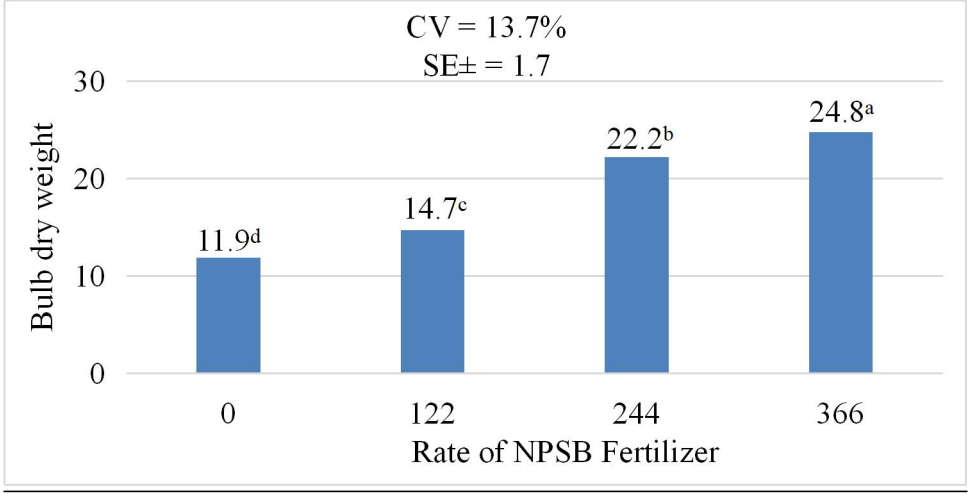


Figure 5. Main effect of NPSB fertilizer on dry bulbs of onion.

Where: *CV = Coefficient of Variation; and SE± = Standard Error. Means with the same letter (s) within a bar are not significantly different each other at 5% (p≤ 0.05) level of significance.*

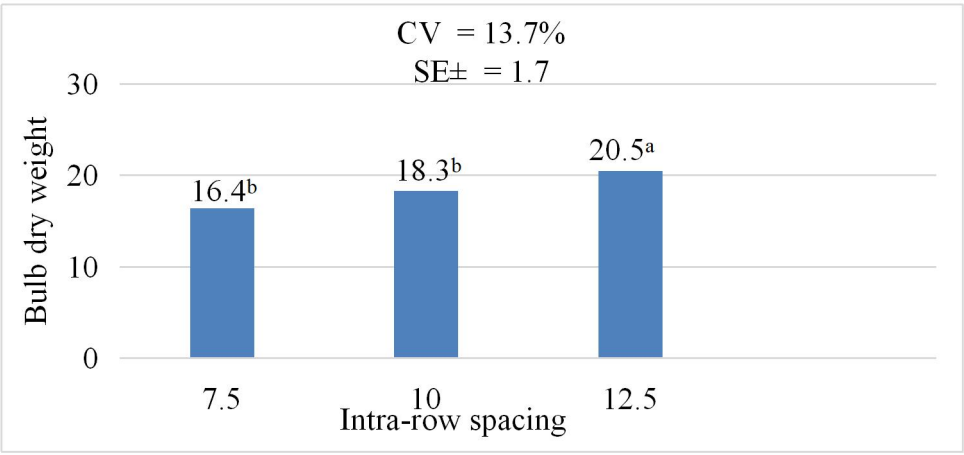


Figure 6. Main effect intra-row spacing on bulb dry weight of onion.

Where: *CV = Coefficient of Variation; SE± = Standard Error. Means with the same letter (s) within a bar are not significantly different each other at 5% (p≤0.05) level of significance.*

4.3.5 Total Dry Biomass (g)

The analysis of variance (ANOVA) indicate that total dry biomass was highly significantly (P≤ 0.01) influenced by the main effects of NPSB fertilizer rate. However, intra-row spacing and their interactions did not show significant difference in the total biomass (P>0.05) (Appendix 2). The maximum total biomass (35.6g) was recorded by the

application of 366kg ha^{-1} NPSB fertilizer. The minimum total dry biomass (18.4) was recorded from plants without NPSB fertilizer rate (Figure 7).

The increase in the amount dry biomass yield in response to increasing NPSB fertilizer rates is likely due to increased NPSB fertilizer supply, which improves plant vegetative growth such as leaf number, leaf diameter, leaf length, and plant height, all of which contribute to improved photosynthesis and assimilate production in the vegetative part of the plant, as well as partitioning to the bulbs (Sharma, 1992). According to Guesh, 2015, Nasreen *et al*. (2007), and El-Tantawy and El-Beik (2009), applying a greater N rate ha^{-1} improved onion dry total biomass yields. Similarly, Pervez *et al*. (2004) found that increased nitrogen dosages resulted in the highest total biomass per plant of radish.

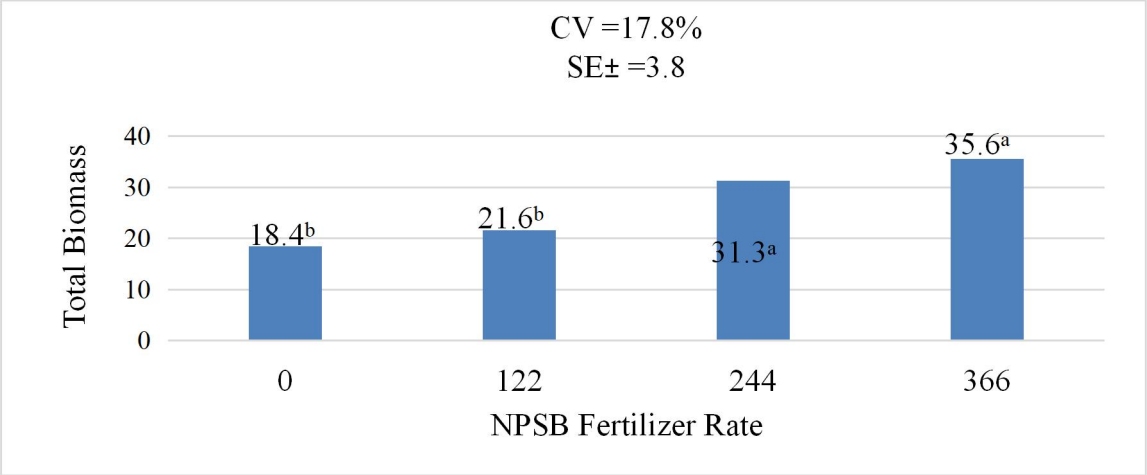


Figure 7. Main effect of NPSB fertilizer on total dry biomass of onion.

***Where**: CV = Coefficient of Variation; SE± = Standard Error. Means with the same letter (s) within a bar are not significantly different each other at 5% (p≤0.05) level of significance.*

4.3.6. Total Marketable Bulb Yield (t ha^{-1})

The analysis of variance revealed that marketable bulb yield of onion was highly significantly (P ≤ 0.01) affected by NPSB fertilizer rate and significantly (P≤0.05) their interaction effects (Appendix 3). However, spacing did not show significant difference in the marketable bulb yield (P>0.05). Generally, marketable bulb yield of onion was increased with increasing NPSB fertilizer rate from 0 to 244kg ha^{-1} with intra-row plant spacing 7.5cm. The highest marketable yield 41.2t ha^{-1}) of onion was achieved from treatment combination of 244kg ha^{-1} NPSB fertilizer and 7.5cm intra-row spacing. The

lowest marketable yield (8.9t ha^{-1}) was recorded from plants grown without NPSB fertilizer and planted at 7.5cm intra-row spacing (Table 5).

This could be due to the presence of plant nutrients that are required from improved growth and development of onion plants that in turn increased the marketable bulb yield. These conditions also improved the diameter and weight of onion bulbs as indicated above that contributed to higher marketable yield with proper size, shaped and color of the bulbs.

These finding is agree with the finding of Solomon *et al*., (2020) who reported that the maximum marketable yield (41157kg ha^{-1}) was observed for plots that received a blended fertilizer rate of 250kg ha^{-1} (NPSB) + 69kg ha^{-1} N top dress. Similarly, increasing the rate of NPS fertilizer increased marketable bulb yield (Amakel, 2020). Muluneh (2016) also discovered that using NPS fertilizer at a rate of 105:119.6:22kg ha^{-1} N: P2O5: S resulted in the maximum marketable yield of onion. Similarly, increasing the nitrogen delivery rate enhanced the marketable bulb yield substantially (Guesh, 2015; Jahan *et al*., 2010; Soleymani and Shahrajabian, 2012). Higher phosphorus levels resulted in significant increases in onion bulb length, diameter, weight, and dry matter content, all of which contributed to increased onion marketable bulb production (Aster, 2009).

El-Shafie and El-Gamaily (2002) and Juszczuk and 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. According to Weldemariam, *et al*. (2015), application of 138kg ha^{-1} N to plants planted at 7.5cm intra-row spacing recorded the highest marketable bulb yield under Gode condition. Similarly, the highest bulb yield (31.6t ha^{-1}) was obtained from the lowest spacing along with nitrogen level of 150kg ha^{-1} and 120kg ha^{-1} (Naik and Hosamani. 2003).

4.3.7. Total Unmarketable Bulb Yield (t ha^{-1})

Unmarketable bulb yield of onion was highly significantly ($P \leq 0.01$) affected by the main effects of blended NPSB fertilizer and intra-row spacing as well as their interaction effects (Appendix 3). The maximum unmarketable bulb yield of onion was obtained from plants supplied with 366kg ha^{-1} NPSB fertilizer and planted with 12.5cm intra-row spacing. The lowest unmarketable bulb yield 0.14t ha^{-1}) was obtained from plants 244kg ha^{-1} NPSB fertilizer and spaced at 7.5cm (Table 5).

Higher unmarketable bulb yield recorded at widest intra-row spacing with 366kg^{-1}ha NPSB level could be due the presence of excess soil nutrients for sub-optimal growth led to over size or weight of bulbs, split bulbs, physiologically disordered, doubles, rotten, off-color and discolor. These research fit with the finding of (Moray *et al.*, 2012) Availability of excess soil nutrients for sub-optimal growth led to over size or weight of bulbs, split bulbs, physiologically disordered, doubles, rotten, off-color and discolor and consequently higher unmarketable yield. In addition to these (Solomon *et al.,* 2020) stated that the maximum unmarketable yield (1273.1kg ha^{-1}) was recorded for plots that received a blended fertilizer rate of 300kg ha^{-1} (NPSB) + 69kg ha^{-1} N top dress. Khan *et al.*, (2002) indicated that application of fertilizer not only improve average bulb weight but also enhance marketable bulbs and significantly reduce the production of unmarketable bulbs by preventing culling or wastage of too much bulbs.

However, these findings contradict the findings of Rumpel *et al*. (2000), who found that lower nitrogen doses increased the output of under-sized bulbs. Similarly, at the maximum planting density and with no nitrogen fertilizer more undersized onion bulbs are gotten (Nasir *et al*., 2007; Jilani *et al*., 2009; Negash *et al*., 2009; Weldemariam *et al*., 2015). It also contradicts the findings of Yemane *et al*. (2013) and Dereje *et al*. (2012), who found that smaller intra-row spacing yielded the largest unmarketable bulb yields of onion and shallot.

4. 3. 8. Total Bulb Yield (t ha^{-1})

The main effects of blended NPSB fertilizer and their interaction highly significantly ($P \leq 0.01$) influenced total bulb yield of onion. However, spacing did not show significant difference in the total bulb yield ($P > 0.05$) (Appendix 4). Total bulb yield of onion increased significantly in response to increasing the rate of NPSB fertilizer application across of the 7.5cm intra-row spacing except in treatment combination of 366kg ha^{-1} with 7.5cm intra-row spacing decreased total bulb yield. The combined treatment of 244kg ha^{-1} NPSB fertilizer and 7.5cm intra-row spacing produced the highest total bulb yield of 41.3t ha^{-1}. Plants planted at 7.5cm intra-row spacing without NPSB fertilizer, on the other hand, generated lower bulbs yield (9.4t ha^{-1}) as shown in Table 4.

The availability of macro plant nutrients in blended NPSB fertilizer may account for the increased output in the fertilizer-needed treatment. This is attributable to the functions of nitrogen in many physiological and metabolic processes, as well as an increase in onion

dry matter production. Similarly, the investigation came to the conclusion that (Nibret, 2020) Plots that received a blended fertilizer rate of 250kg ha^{-1} (NPSB) + 69kg ha^{-1} N top dress produced the best overall yield (42378kg ha^{-1}).

According to Shinde (2014) the increased in total bulb yield could be due to better uptake of nutrients from soil that might have contributed to increased plant height, number of leaves, bulb diameter and weight of bulb. The highest total bulb yield was obtained from NPSB fertilizer rate at the concentration of 385.86kg ha^{-1} NPS (Muluneh, 2016).

The findings are also consistent with those of (Abraha *et al*., 2013), who found that fertilizer combinations of N, P, S, and Zn had a positive impact on onion bulb diameter development, which adds to overall bulb output. According to various studies, applying phosphorus to increase the size of onion bulbs resulted in a higher total bulb yield (Costa *et al*, 2009; Dudhat *et al*., 2010; Wamser *et al*., 2011; Tibebu *et al*., 2014; Resende *et al*., 2016). Kalid (2019) also discovered that adding micro nutrients at a rate of 0.5 percent zinc sulfate (ZnSO4), 1.0 percent iron sulfate (FeSO4), and 1.0 percent boron to onions significantly increased onion yield (B at 0.5 percent).

4.3.9. Harvesting Index (%)

The analysis of variance showed that means of harvesting index was significantly ($P \leq 0.01$) affected by the interaction effect of NPSB Fertilizer and intra-row spacing. Moreover, harvesting index was significantly ($P \leq 0.01$) influenced by the main effects of NPSB fertilizer application and intra-row spacing) (Appendix 4).

Harvesting index increasing significantly as the rate of NPSB fertilizer application was raised in tandem with the closest intra-row spacing. As a result, the best harvesting index was obtained by applying NPSB fertilizer at a rate of 244kg ha^{-1} with the narrowest intra-row spacing. On the other hand, onion plants without NPSB fertilizer and at 7.5cm had the lowest Harvesting index (Table 5).

This study agrees in part with the findings of (Guase Tekle, 2015), who found that the most nitrogen fertilizer and widest intra-row spacing resulted in shorter leaf length, leaf diameter, and plant height, which may have resulted in lower above ground biomass and a higher harvesting index. Abdissa *et al*. (2011) found a similar impact when they found that the lowest onion harvest index occurred when no nitrogen fertilizer was applied. Similarly,

Yemane *et al*. (2013) found that wider intra-row spacing reduced harvest indices in onion while Dereje *et al*. (2012) found that wider intra-row spacing reduced harvest indices in shallot. Furthermore, because of the lower vegetative biomass, the highest values of the mungbean harvest index were previously reported with closer spacing (Kabir and Sarkar, 2008).

Table 5. Interaction effect of NPSB blended fertilizer rate and intra-row spacing on bulb yield parameters of Onion.

NPSB fertilizer (kg ha^{-1})	Intra-row (cm)	MBY (t ha^{-1})	UNMBY (t ha^{-1})	TBY(t ha^{-1})	HI (%)
0	7.5	8.9^{g}	0.5^{abc}	9.4^{g}	58.8^{d}
	10	13.2^{fg}	0.31^{def}	13.54^{fg}	65.47^{c}
	12.5	16.2^{ef}	035^{cde}	16.59^{ef}	69.63^{bc}
122	7.5	20.17^{de}	0.52^{ab}	20.68^{de}	64.83^{c}
	10	22.17^{cd}	0.18^{fg}	22.32^{cd}	68.23^{bc}
	12.5	25.27^{c}	0.49^{abc}	23.75^{c}	70.3^{bc}
244	7.5	41.2^{a}	0.14^{g}	41.3^{a}	77.17^{a}
	10	34.27^{b}	0.26^{efg}	34.49^{b}	68.78^{bc}
	12.5	37.07^{ab}	0.29^{def}	37.36^{ab}	73.37^{ab}
366	7.5	37.63^{ab}	0.4^{bcde}	38.03^{ab}	66.57^{c}
	10	38.27^{ab}	0.43^{abcd}	38.56^{ab}	66.6^{c}
	12.5	38.2^{ab}	0.56^{a}	38.67^{ab}	70.5^{bc}
SE±		1.3	0.04	1.3	1.46
CV (%)		10.0	23.59	9.8	4.5

Where: *MBY =Marketable Bulb yield; UNMBY=Unmarketable Bulb Yield; TBY=Total Bulb Yield; HI =Harvesting Index; SE±=Standard Error; and CV = Coefficient of Variation.*

Means with the same letter(s) within a column are not significantly different each other at 5% ($p \leq 0.05$) level of significance.

4.4. Correlation Analysis

Correlation coefficient (r) values, computed to decide the relationships between and within each pair of the characters, are in Table 6. The correlation values showed obvious affiliation of the variables with every other, and certainly indicated the magnitude and course of the affiliation and relationships. Results of the correlation analysis revealed that marketable bulb yield was positively and highly significantly (P<0.01) correlated with plant height (r= 0.41**), leaf length (r= 0.62**) number of leaves (r=0.72**),leaf dry weight (r=0.61**), bulb length (r= 0.86**), bulb diameter (r=0.69**), fresh bulb weight

(r= 0.67**), Bulb dry weight (r= 0.83**), total dry biomass (r= 0.78**), total bulb yield (r= 0.99**) and Harvesting index (r=0.6**). The feasible reason for the observed association between total bulb yield and these variables could be because increase in plant height and number of leaves produced higher photosynthesis, which in turn resulted in vigorous vegetative boom and those plants gave higher marketable and unmarketable bulb yield and as a end result the total bulb yield of onion increased.

Table 6. Correlation Coefficient among different variables of onion.

	PH	LL	LN	LDW	FBW	DBW	BL	BD	TDB	MBY	UNMBY	TBY	HI
PH	1.0												
LL	0.66^{**}	1.0											
LN	0.44^{**}	0.66^{**}	1.0										
LDW	0.67^{**}	0.72^{**}	0.64^{**}	1.0									
FBW	0.6^{**}	0.64^{**}	0.68^{**}	0.63^{**}	1.0								
DBW	0.51^{**}	0.67^{**}	0.67^{**}	0.64^{**}	0.82^{**}	1.0							
BL	0.65^{**}	0.72^{**}	0.64^{**}	0.71^{**}	0.64^{**}	0.75^{**}	1.0						
BD	0.75^{**}	0.75^{**}	0.68^{**}	0.67^{**}	0.83^{**}	0.71^{**}	0.9^{**}	1.0					
TDB	0.64^{**}	0.68^{**}	0.73^{**}	0.85^{**}	0.77^{**}	0.68^{**}	0.83^{**}	0.91^{**}	1.0				
MBY	0.41^{**}	0.62^{**}	0.72^{**}	0.61^{**}	0.67^{**}	0.83^{**}	0.69^{**}	0.69^{**}	0.78^{**}	1.0			
UNMBY	0.083^{**}	0.063^{NS}	-0.18^{NS}	-0.16	-0.12^{NS}	-0.073^{NS}	0.14^{NS}	0.13^{NS}	-0.14^{NS}	0.2^{NS}	1.0		
TBY	0.42^{**}	0.62^{**}	0.71^{**}	0.77	0.67^{**}	0.84^{**}	0.69^{**}	0.7^{**}	0.81^{**}	0.99^{**}	-0.19^{NS}	1.0	
HI	0.45^{**}	0.43^{**}	0.59^{**}	0.69	0.43^{**}	0.32^{**}	0.43^{**}	0.55^{**}	0.67^{**}	0.6^{**}	0.36^{**}	0.59^{**}	1.0

Where: *NS=non-significant; *=Significant; and **=highly significance differences at 5% ($p \leq 0.05$) level of probability; PH = Plant Height, LL = Leaf Length; LN = Leaf Number; LDW= Leaf Dry Weight ; FBW = Fresh Bulb Weight; BD = Bulb Diameter;TDB= Total Dry Biomass; BDW= Bulb Dry Weight; BL = Bulb Length; MBY = Marketable Bulb Yield; UNMBY = Unmarketable Bulb Yield; TBY = Total Bulb Yield; and HI = Harvesting Index Respectively.*

4.5. Partial Budget Analysis

The economic analysis was done to evaluate the benefits of each treatment where the costs of NPSB fertilizer (15Birr kg^{-1}), onion seeds (Birr 1000kg^{-1}) and labor cost to NPSB fertilizer application, transplanting (Birr 150 $person^{-1}$) were considered as variable costs. About 4.6, 3.5 and 2.8kg ha^{-1} onion seeds were required for 7.5, 10 and 12.5cm intra-row spacing. The farm get price of the marketable yield of onion during the time of harvesting was Birr 25kg^{-1}, which was used in the present study. Accordingly, the highest net benefit (Birr 893,390) was obtained from the treatment combination of 244kg ha^{-1} NPSB fertilizer and 7.5cm intra-row spacing. The lowest net benefit (Birr 173,900) was recorded from plants without NPSB fertilizer and planted at 7.5cm intra-row spacing indicated in Table 7.

Table 7. Partial budget analysis of onion as influenced by NPSB fertilizer rate and intra row spacing at Enemor district during the 2021 irrigation season.

Treatment combination	Marketable Bulb Yield (t ha^{-1})	Actual Marketable Yield (Kg ha^{-1})	Actual Marketable Yield - 10% (kg ha^{-1})	Adjusted Marketable Yield (kg ha^{-1}	Total Gross Return (Birr ha^{-1})	Cost of NPSB Fertilizer (Birr ha^{-1})	Cost of labor for fertilizer applied	Cost of Onion Seed (Birr ha^{-1})	Cost of labor for transplanting	Total Variable Cost (Birr ha^{-1})	Net Benefit (Birr ha^{-1})
7.5*0	8.9	8900	890	8010	200,250	0	0	4600	21,750	26,350	173,900
10*0	13.2	13200	1320	11,880	297,000	0	0	3500	14,400	18,050	278,950
12.5*0	16.2	16200	1620	14,580	364,500	0	0	2800	7200	10,000	354,500
7.5*122	20.17	20170	2017	18,153	453,825	1830	1800	4600	21,750	29,980	423,845
10*122	22.17	22170	2217	19,953	498,825	1830	1800	3500	14,400	21,680	477,147
12.5*122	25.27	25270	2527	22,743	568,575	1830	1800	2800	7200	13,630	554,945
7.5*244	41.2	41200	4120	37,080	927,000	3660	3600	4600	21,750	33,610	893,390
10*244	34.27	34270	3427	30.843	771,075	3660	3600	3500	14,400	25,310	745.765
12.5*244	37.07	37070	3707	33,363	834,073	3660	3600	2800	7200	17,260	816,813
7.5*366	37.63	37630	3763	33,867	846,675	5490	5400	4600	21,750	37,240	809,435
10*366	38.27	38270	3827	34,443	861,075	5490	5400	3500	14,400	28,700	832,135
12.5*366	38.2	38200	3820	34,380	859,500	5490	5400	2800	7200	20,890	838,,610

Table 8. Dominance analysis of onion as influenced by NPSB fertilizer rate and intra-row spacing at Enemor during 2021 under irrigation season.

Total Variable Cost (Birr ha^{-1})	Net Benefit (Birr ha^{-1})	Dominance
10,000	354,500	
13,630	554,945	
17,260	816,813	
18,050	278,950	D
21,680	477,147	
25,310	745,745	
26,350	173,900	D
28,940	832,175	
29,980	423,845	
33,610	893,390	
37,240	809,435	

Where: *D = Dominance*

Table 9. Marginal Rate Return (MRR) of onion as influence by NPSB fertilizer rate and intra-row spacing at Enemor District during 2021 under irrigation Season.

Treatment combination	Total Variable Cost (Birr ha^{-1})	Net Benefit (Birr ha^{-1})	MRR (%)
12.5*0	10,000	354,500	0
12.5*122	13,630	554,945	5522
12.5*244	17,260	816,813	6368
10*244	25,160	745,765	2556
10*366	28,700	832.135	2474
7.5*244	33,610	893,390	2282

Where*: MRR (%) = (Change in Net Benefit /Change in Variable Cost) ×100%*

5. CONCLUSION AND RECOMMENDATIONS

5.1. Conclusion

The results of the present study clearly showed that NPSB fertilizers and intra-row spacing affected the growth and yield performance of onion under Enemor District conditions. This was specifically reflected on plant height and number of leaves as well as the length, diameter and weight of the bulbs. Accordingly, this combined application of 244kg ha^{-1} on NPSB and 7.5cm intra-row spacing gave the best marketable yield of 41.2t ha^{-1}, which is averagely 78.4% increase when compared to the other treatment combinations tested.

On the other hand, the correlation analysis of plant height, length, and number of leaves, bulb length, bulb diameter as well as the fresh and dry bulb weight, including the total bulb yield showed a highly significant and positive correlation with the marketable bulb yield of onion. As such, the present findings has concurred with previous findings reported by CIMMYT (1988) in that the highest net benefit of onion was recorded from the treatment combination of 244kg ha^{-1} NPSB fertilizer and narrow intra-row spacing.

5.2. Recommendations

Based on the results of the present study, the application of 244 kg ha^{-1} of NPSB fertilizer with narrow intra-row spacing is recommended for onion production in Enemor District as well as areas with similar agro-ecological conditions. This was economically substantiated by the partial budget analysis, which showed the highest net benefit increase of Birr 893,390 while using the stated treatment combination as compared to the others tested. Besides, since the study was conducted only for a single season and in only one location, further research is recommended to be carried out in more other locations as well as at different seasons.

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7. APPENDICES

Appendix 1. Mean squares from analysis of Variance (ANOVA) for leaf length, plant height and Number per plant of onion as influenced by blended NPSB fertilizer rate and intra-row plant spacing.

Source of variation	DF	Mean of squares			
		LL(cm)	NL	PH(cm)	LDW(g)
Rep	2	73.4	0.5	159.3	2.8
NPSB	3	225.2**	16.6**	867.0**	35.4**
IRS	2	209.8**	24.8**	300.5**	4.5^{NS}
NPSB*IRS	6	16.8^{NS}	4.7*	76.8**	6.2^{NS}
Error	22	16.5	0.93	15.6	4.8
CV (%)		10.8	13.1	7.9	26.4

Where: *LL = Leaf Length; NL = Number of leaf per plant; PH= Plant Height; DWL = Leaf Dry Weight; DF = degrees of freedom; NS, * and ** implies non-significant; Significant and highly significance differences at 5% ($p \leq 0.05$) level of probability respectively.*

Appendix 2. Mean square from analysis of Variance (ANOVA) for Bulb length, bulb diameter and fresh weight of onion as influence by blended NPSB fertilizer rate and intra-row plant spacing.

Source of variation		Mean of squares		
	DF	BL(cm)	BD(cm)	FBW(g)
Rep	2	0.9	2.1	1.8
IRS	2	3.4**	7.5**	2588**
NPSB	3	4.0**	6.7**	1889**
IRS*NPSB	6	0.3*	0.4**	216**
Error	22	0.08	0.03	37.3
CV(%)		6.3	3.7	10.9

Where: *BL = Bulb Length;BD= Bulb Diameter; FBW= Fresh Bulb Weight; DF = degrees of freedom; NS= non-significant; * = Significant; and ** = highly significance differences at 5% ($p \leq 0.05$) level of probability respectively.*

Appendix 3. Mean squares from analysis of Variance (ANOVA) for Bulb dry weight, Marketable bulb and Unmarketable bulb of onion as influenced by blended NPSB fertilizer rate and intra-row plant spacing.

Source of variation	DF	Mean of squares			
		BDW	TDB	MBY	UMBY
Rep	2	0.1	6.5	0.7	0.014
IRS	2	51.13**	38.3^{NS}	19.6^{NS}	0.05**
NPSB	3	334.4**	582**	1356.2**	0.09**
NPSB*IRS	6	11.3^{NS}	27.2^{NS}	26.0*	0.04**
Error	22	6.4	21.8	7.7	0.008
CV		13.7	17.5	10.0	23.6

Where: *BDW =Bulb Dry Weight;TDB = Total Dry Bio-Mass; MBY = Marketable Bulb Yield; UMBY = Unmarketable Bulb Yield; DF = Degrees of Freedom; NS = Non-Significant; *= Significant; and ** = highly significance differences at 5% ($p \leq 0.05$) level of probability respectively.*

Appendix 4. Mean square from analysis of variance (ANOVA) for Harvesting Index and Total yield of onion as influenced by blended NPSB fertilizer rate and intra-row plant spacing.

Source of variation		Mean of squares	
	DF	HI	TY
Rep	2	10.2	0.4
IRS	2	61.5*	21.1^{NS}
NPSB	3	110.7**	1346.4**
IRS*NPSB	6	39.9**	24.6*
Error	22	9.6	7.6
CV(%)		4.5	9.8

Where: *HI = Harvesting Index; TY = Total Bulb Yield; DF = degrees of freedom; NS=significant; * Significant; and ** = Highly Significance Differences at 5% ($p \leq 0.05$) level of probability respectively.*