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Impact of Blended Mineral NPSB and Urea Fertilizer Rates on the Growth, Yield, and Yield Components of Onion (*Allium cepa* L.) in Mersa, Northeastern Ethiopia

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Abstract

Onion (*Allium cepa* L.) is one of the most significant vegetable crops cultivated extensively in Ethiopia, especially in the northeastern region. However, due to environmental stresses, its productivity is lower than the world average. The lack of improved varieties, postharvest losses, diseases and pests, low soil fertility, and inadequate plant nutrients are key constraints limiting its productivity. An experiment was conducted at the Mersa College of Agriculture Research Station, Woldia University, to optimize the rates of blended NPSB and urea fertilizer for improving onion crop growth, yield, and quality. The experiment involved a factorial combination of four NPSB rates (0, 100, 200, and 300 kg/ha^{1}) and four urea rates (0, 100, 150, and 200 kg/ha), arranged in a Randomized Complete Block Design with three replications. The analysis of variance indicated that the interaction between blended NPSB and urea fertilizer significantly affected the days to 70% physiological maturity, plant height, leaf length, mean bulb weight, and both marketable and total bulb yields. Leaf and bulb diameter, neck thickness, dry weight, cumulative weight loss, bulb sprouting, and rotting percentage were significantly influenced by the main effects of blended NPSB and urea fertilizer rates. The highest total bulb yield (41.4 t/ha ^{1}) and marketable bulb yield (40.58 t/ha), along with the maximum net benefit (1,812,053 ETB/ha) at an acceptable MRR (7469%), were achieved with the combination of 200 kg ha^{-1} blended NPSB and 150 kg/ha urea. Therefore, to maximize onion productivity in the study area and similar agroecologies, it is essential to apply economically feasible rates of 200 kg/ha blended NPSB combined with 150 kg/ha urea. However, the experiment should be repeated over different seasons and locations to make a decisive recommendation.

Keywords*:* Growth;; marketable yield; NPSB;; onion production; phenology; urea fertilizer; weight loss

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Introduction

Onion, a bulb crop (Welbaum, 2015), originates from southwestern Asia (Brewster, 2008). In Ethiopia, onions are cultivated both as a spice and as a vegetable crop. Their unique taste and aroma not only enhance food seasoning but also offer medicinal properties (Anteneh Aweke and Diriba Shiferaw, 2024).

Onions are cultivated using irrigation and rain-fed circumstances in Ethiopia (Chala Kitila et al., 2022). In Ethiopia, 25,237.55 hectares of land were used to onion cultivation, producing 207,662.67 tons with productivity of 8.23 t/ha during the meher season (CSA, 2021/22). This productivity is lower compared to Republic of Korea, USA, Holland, Japan, and Egypt, which have productivities of 66.15 t/ha, 56.13 t/ha, 51.64 t/ha, 46.64 t ha^{-1}, and 36.16 t/ha, respectively (FAOSTAT, 2021). The factors contributed for low productivity are diseases, pests, lack of high-yielding varieties, depleted soil fertility, moisture stress, inappropriate use of plant nutrients, and repeated drought (Chala Kitila et al., 2022).

Soil fertility in Ethiopia is declining due to nutrient depletion, mono-cropping, and the removal of crop residues from farms (Antene Aweke and Diriba-Shiferaw, 2024). Di-ammonium phosphate (DAP) and urea, which provide phosphorus and nitrogen fertilizers were used in the study area. However, the use of these fertilizers alone has not addressed soil fertility and crop requirements because of the lack of other macro and micronutrients (EthioSIS, 2014). To address this issue, the Ministry of Agriculture introduced blended NPSB fertilizer to replace DAP, which contains nitrogen (18.9% N), phosphorus (37.7% P_2O_5), sulfur (6.95% S), and boron (0.1% B) (Muluneh Nigatu et al., 2018).

The mineral fertilizers application, which plays a crucial role in growth and productivity of onion, is highly indispensable. Depending on the environment and soil types, onion plants, being shallow-rooted and nutrient-hungry, require an adequate and balanced supply of the main plant nutrients such as nitrogen, phosphorus, and sulfur (Kelem Muluneh et al., 2024) as well as micronutrients (Seid et al., 2022). Kibebew Fikre et al. (2021) recommended using 92 kg/ha N in split form for dry bulb production in the Upper Awash areas. Producers in this area applied 200 kg/ha DAP and 100 kg/ha urea for their onion crops (Lemma Dessalegn and

Shimelis Aklilu, 2003). According to Pramanik and Tripathy (2017), onions can achieve their highest yield potential when micronutrients like boron and zinc are applied alongside nitrogen and phosphorus. Economical onion production was increased through the application of 105/119.6/22 kg/ha NPS (Muluneh Nigatu et al., 2018). Mohammed Ahmed and Muhammed Sitote (2024) recommend the use of 100 kg/ha NPS in combination with 100 kg/ha urea fertilizers to enhance onion crop productivity and profitability.

The application of NPSB differs depending up on the variety, agroecology, and purpose of the crop. However, farmers in the study area use urea and inappropriate blended NPSB fertilizer levels which contribute to high yield reduction. Many farmers still practice 100 kg/ha urea and 200 kg/ha DAP (substituted by NPSB) for onion production in the area (Alemu Molla, 2020), which may not suit the nutrient requirements of onions. Farmers in the study area understand how onions respond to applied nutrients; however, they lack knowledge about the specific types and rates of fertilizers needed to enhance yield. As a result, one of the primary issues causing reduced onion yields in the area is the absence of optimal and economically feasible fertilizer recommendations tailored to the local soil conditions. Consequently, it is crucial to determine the optimum and economic feasibility of using NPSB combined with urea fertilizer rates to improve the growth, yield components, yield, and quality of onions in the study area.

Materials and Methods

Study Area and Experimental Materials Description

The experiment was carried out at Woldia University Site, (Fig. 1) during the cropping season of 2022/2023 using irrigation. Geographically, the site is situated 490 km, northeastern Ethiopia at 11o35'N 39o38'E longitude, with an altitude of 1600 meter above sea level (m.a.s.l.). The area experiences average annual rainfall between 750 and 1000mm, characterized by a bimodal (belg and meher) pattern (SARC, 2008). The mean annual minimum and maximum temperatures are 15°C and 28.5°C, respectively (HARDO, 2019). The soil in the region is classified as clay loam with a pH range from slightly acidic to slightly alkaline (Daniel Zewdu et al., 2021). Commonly grown crops include Onion (*Allium cepa* L.), Tomato (*Solanum esculentum* Mill.), Teff (*Eragrostis tef*), Maize (*Zea mays* L.), and Sorghum (*Sorghum bicolor*) (HARDO, 2018). The Adama Red onion variety, developed by the Melkasa Agricultural Research Center, was chosen for this study due to its high yield, strong pungency, disease resistance, and widespread adoption by farmers. This variety is well-regarded by both producers and consumers and is successfully cultivated by smallholder farmers (MoA, 2012). Both blended NPSB fertilizer (containing 18.9% N, 37.7% P_2O_5, 6.95% S, and 0.1% B) and Urea (46% N) were used as fertilizer sources. These fertilizers were procured from the Buhoro Basic Farmers' Cooperative Association Shopping Center in Mersa town.

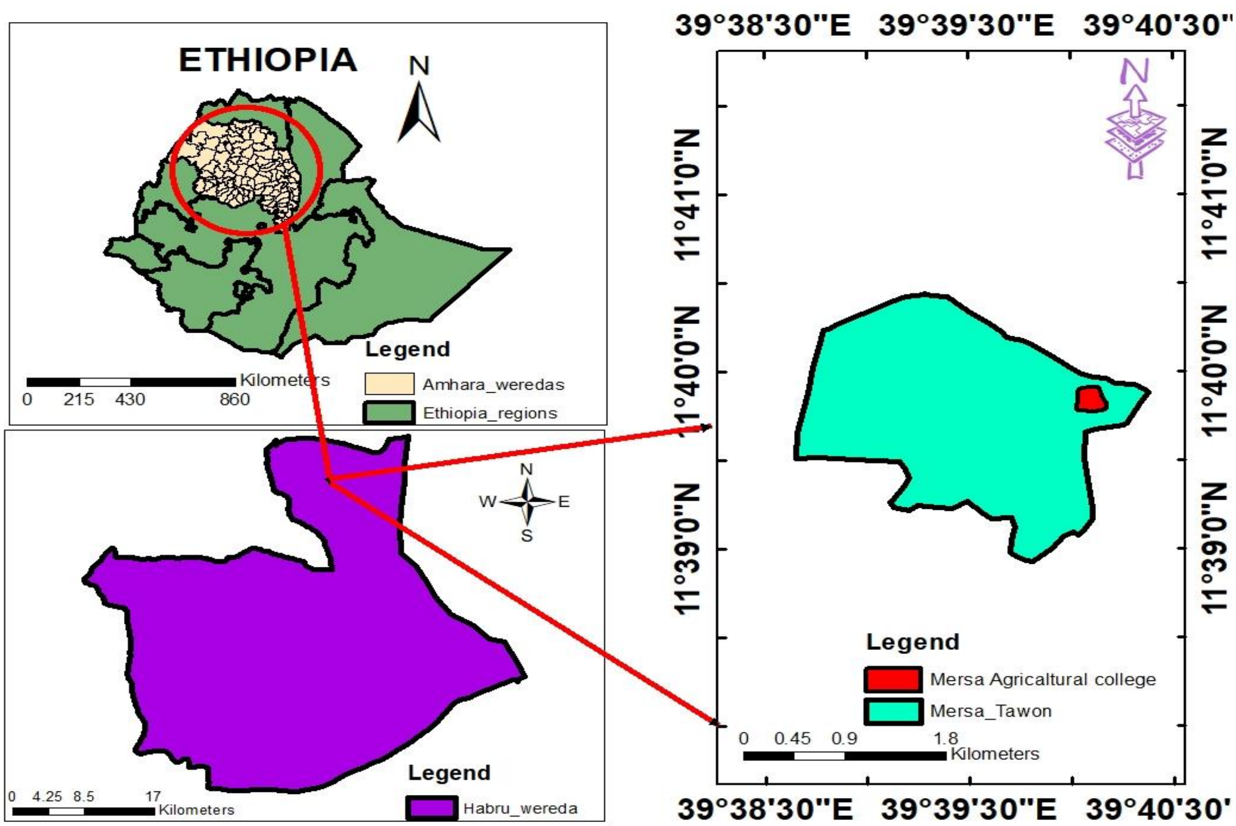

Figure 1: Map of the study area

Treatments, Experimental Design, and Procedures

The treatments involved a combination of four levels of blended NPSB (0, 100, 200, and 300 kg/ha) and four levels of urea (0, 100, 150, and 200 kg/ha). A 4x4 factorial arrangement was designed in a RCB design, with three replications. The full rate of NPSB was applied at transplanting, while the urea fertilizer was applied in two halves:

the first half at 15 days after transplanting (DAT), and the remaining half at 45 DAT, to prevent leaching (MoA, 2009). Each fertilizer treatment was applied using the band placement method, where fertilizers were placed into the soil near the seedlings.

Seedlings were raised on thoroughly prepared beds measuring 1m x 5m, raised 10 cm from the surface. Then seeds were lightly covered with soil and grass mulch to conserve moisture and ensure uniform seed germination. Following seedling emergence, the mulch was slowly removed with care to avoid that exposing to desiccation. The experimental land was plowed using an oxen plow to physically pulverize, level, and break clods. Hoes and spades were then used to prepare the experimental plots for transplanting. The total experimental field area was 479.4 m², with gross and net plot areas of 4.8 m² and 4.14 m², respectively. Each plot contained 8 single rows, 6 of which central rows holding 20 plants per row. The distances between adjacent experimental units and replications were 1 m and 1.5m, respectively. Well performed seedlings with 3-4 true leaves were selected and transplanted to the experimental field 45 DAS (Lemma Dessalegn and Shimelis Aklilu, 2003; Tekalign Tsegaw et al., 2012). Before picking up, the experimental units were irrigated to make the easy removal of the seedlings. Planting was done on ridges of the furrow (40 cm), row (20 cm) and plat to plant spacing (10 cm) for all treatments.

Pre-Planting Soil Sample Analysis

Soil samples were collected from experimental land in a zigzag pattern in sixteen spots at the depth of 0–30 cm and combined into one composite sample. The collected samples were then air-dried and ground to pass through a 2mm sieve. The physicochemical properties include soil texture (Day 1965), pH (Sparks et al., 2020), cation exchange capacity (Chapman, 1965), organic carbon (Dewis and Freitas, 1970), total nitrogen (tN) (Dewis and Freitas, 1970), and available phosphorus (avP) (Olsen and Dean, 1965) were analyzed using standard procedures at the Debre Birhan Agricultural Research Center Soil and Water Laboratory.

Crop Data Collection

The number of days was recorded through observation once at 70% of physiological maturity and. Growth (plant height, leaf length, and leaf diameter), yield parameters (bulb diameter, bulb neck thickness, average bulb weight, marketable and total bulb yield), quality parameters (dry matter content) and storability parameters (weight losses, sprouting and rot losses) were collected using standard methods.

$$\text{HI} = \frac{Bulb\ Yield}{Biological\ Yield} X100$$

Bulb yield is the economic yield while biological yield is the bulb yield + the above-ground shoot yield.

The dry matter content (DMC) was measured standard methods:

$$\text{DMC}\ (\%) = \frac{[(DW + CW) - CW]}{[(FW + CW) - CW]} X100$$

Where, DMC represents dry matter content, DW represents dry weight, CW represents container weight, and FW represents fresh weight.

The physiological weight loss of the bulbs was then determined using the methods described by Wasker et al. (1999).

The percentage sprout loss (SL) was determined based on Obetta et al. (2007) and Abubakar et al. (2019):

$$\text{SL}(\%) = \frac{1 - Nh}{Nt} X100$$

Where Nh represents the number of healthy bulbs retained, and Nt represents the total number of stored onion bulbs.

The rot loss (RL) was calculated using the equation described by Obetta et al. (2007):

$$\text{RL}(\%) = \frac{1 - Nr}{Nt} X100$$

Where Nr represents the number of rotten onion bulbs, and Nt represents the total number of onion bulbs.

Partial Budget Analysis

This was done following the CIMMYT (1988) guidelines.

Data Analysis

The data were analyzed using analysis of variance (ANOVA) with SAS version 9.3 (SAS, 2012). Treatment means were compared using Least Significant Difference (LSD) at a 5% probability level.

Results and Discussion

Soil Physicochemical Properties

The soil was classified as clay with 21% sand, 50% clay, and 29% silt. Pre-planting soil analysis indicated the pH was neutral, having a pH value of 7. Onion can optimally be produced on soils ranging in pH between 6 and 8 (Lee et al., 2014). Hence, the pH was favorable for onion production. The organic matter (OM) of the soil was low according to the categories outlined by Tekalign Tadesse (1991). The tN value of the soil is 0.12%, which is below the ideal level (0.2%) for crop productivity in most Ethiopian soils (EthioSIS, 2013). The available sulfur (avS) of the soil was 18.59 ppm, which is also considered low (Jackson, 1958). The results indicated that since onions are sulfur-loving plants, it is crucial to supply sulfur fertilizer to the experimental area (Mishu et al., 2013). The soil is low in avP (14.12 ppm) (Olsen and Dean, 1965). This is 6.23% lower than the ideal phosphorus level for most Ethiopian soils (EthioSIS, 2013). The low levels of tN and avP suggest that external nutrient application may be needed as per the recommendations for onion crops. Based on Landon's (1991) classification, the soil's cation exchange capacity (CEC) is high (58.00 cmol/kg).

Table 1: Physicochemical properties of soil prior to planting

Characteristics of soil	**Values**	**Rating**	**Source**
Depth (cm)	0-30		
pH (1:2.5 H_2O)	7.00	Neutral	Hazelton and Murphy (2007)
Organic carbon (%)	1.06	Moderate	Walkley and Black, (1934)
Organic matter (%)	1.83	Low	Tekalign Tadesse (1991)
Electrical conductivity (ds/m)	0.48	Slightly saline	
CEC (cmol/kg)	58.00	High	Scollenberger and Simon, (1945)
TN (%)	0.12	Low	EthioSIS, 2013
AvP (ppm)	14.12	Low	Olsen and Dean (1965)
AvS (ppm)	18.59	Low	Jackson, (1958)
Ca (meq/100g)	43.15	Moderate	Hazelton and Murphy (2007)
Mg (meq/100g)	12.25	Moderate	Hazelton and Murphy (2007)
C/N ratio	8.91		
Soil particle size composition			
Sand (%)	21		
Clay (%)	50		
Silt (%)	29		
Soil textural class	Clay		Day, (1965)

Days to 70% physiological maturity (DM)

Blended NPSB, urea, and their combination affected onion maturity significantly ($p<0.01$). The onion crop treated with 300 kg/ha NPSB + 200 kg/ha urea matured later (130.67 days), though statistically similar to the maturity days obtained from treatments with 100 kg/ha NPSB + 200 kg/ha urea (126.00 days), 200 kg/ha NPSB + 200 kg/ha urea (128.00 days), and 300 kg/ha NPSB + 150 kg/ha urea (129.67 days). The shortest maturity period (104.67 days) was observed in the control group. Therefore, applying 300 kg/ha NPSB + 200 kg/ha urea delayed maturity by 26 days in contrast to the control (Table 2).

The presence of nitrogen in both blended NPSB (18.9% N) and urea (46% N) likely promoted stronger vegetative development for a longer period before the onset of the reproductive phase, which may have delayed crop maturity. In general, the addition of nitrogen is vital for the synthesis of key macromolecules, such as proteins and enzymes, which are crucial for maintaining and producing vegetative tissues, thus contributing to the delayed maturity of onions (Alebachew Merawi et al., 2019). Similarly, Seid et al. (2023) reported that the physiological maturity of hot pepper is delayed with increased levels of urea and NPSB.

Plant height (PH)

NPSB blended, urea and NPSB*urea significantly ($P < 0.05$) affected the onion plant height (PH). The tallest plant (84.33 cm) was observed at 300 kg/ha NPSB + 200 kg/ha urea, the shortest (51.67 cm) from untreated onion. Consequently, the tallest plants showed 32.66 cm increase in their height as compared to no fertilizer application (Table 2).

The provision of sufficient and stable nutrients from the inorganic blended NPSB combined with urea may enhance cell elongation, leading to maximum plant height. This can be attributed to N, present in both blended fertilizers and urea, which promotes the synthesis of proteins, enzymes, pigments, hormones, etc., and enhances the physiological processes that influence cell segmentation and extension, subsequently increasing plant height. These findings align with Alebachew Merawi et al. (2019), who reported that increasing nitrogen rates improved onion plant height. Phosphorus is crucial for shoot and root tips, where high metabolism and rapid cell division take place. Additionally, the 37.7% phosphorus content in blended NPSB may encourage the development of fibrous and lateral roots. Sulfur (7%) aids in nutrient absorption, resulting in enhanced growth and increased plant height (Mandefro Tilahun et al., 2020). Furthermore, sulfur encourages chlorophyll production, boosts photosynthetic activity, and supports robust vegetative development, resulting in taller plants. boron in the NPSB may significantly enhances this parameter as its essential role in cell division and nitrogen absorption from the soil, which further promotes plant growth and height (Shawl Assefa et al., 2022). In line with this, Seid et al. (2023) noted maximum (79.76 cm) height of hot pepper at 300 kg/ha blended NPSB + 150 kg/ha urea.

Table 2: Interaction effect of blended NPSB and urea fertilizers on phenological and growth characteristics of onion

Urea(kg/ha)	Days to 70% maturity				PH (cm)				LL (cm)			
	NPSB (kg/ha)				NPSB (kg ha^{-1})				NPSB (kg ha^{-1})			
	0	100	200	300	0	100	200	300	0	100	200	300
0	104.7^{g}	111.7^{fg}	112.3^{f}	117.7^{d-f}	51.7^{h}	58.3^{gh}	70.3^{d-f}	73.7^{b-e}	48.2^{fg}	50.7^{ef}	44.2^{g}	44.0^{g}
100	115.3^{def}	114.3^{d-f}	116.3^{d-f}	112.7^{ef}	64.3^{e-g}	69.7^{d-f}	73.0^{c-e}	66.0^{d-g}	48.3^{fg}	55.7^{c-e}	54.7^{de}	56.3^{b-e}
150	120.0^{c-e}	118.33^{d-f}	121.0^{b-d}	129.7^{a}	70.3^{d-f}	72.3^{c-e}	74.7^{a-d}	83.3^{ab}	54.7^{de}	56.7^{b-d}	60.0^{b-d}	61.7 b
200	114.3^{d-f}	126.0^{a-c}	128.0^{ab}	130.7^{a}	60.7^{fgh}	80.7^{a-c}	81.0^{a-c}	84.3^{a}	61.0^{bc}	60.7^{bc}	61.3^{bc}	68.3^{a}
LSD (5%)	7.55				10.01				5.74			
F-test	**				*				**			
CV (%)	3.69				8.51				6.31			

Mean values sharing the same letter in each column are not significantly different at a 5 % probability level

Leaf length (LL)

The LL was significantly (P<0.01) affected by blended NPSB, urea and by the interaction of the two fertilizers. Longest LL (68.33 cm) was observed at 300 kg/ha NPSB + 200 kg/ha urea, while the shortest LL (44.00 cm) was observed in plots treated with 300 kg/ha NPSB and 0 kg/ha urea, which was statistically similar to the LL in the control. The tallest LL showed about 55.3% increase in length compared to the control (Table 2).

The presence of N in the blended NPSB and urea fertilizers likely contributed to higher photosyntate manufacturing, subsequently enhanced vegetative growth and increased LL. Furthermore, S and P in the NPSB may play a significant role in enhancing the root and shoot systems of onions, thereby contributing to leaf length. In line with this, Alemu Molla et al. (2020) and Gosa Shura et al. (2022) pointed out an increase in LL with higher rates of NPSB. Similarly, Zaman et al. (2011) found that applying nitrogen at a rate of 200 kg/ha and sulfur at a rate of 45 kg/ha resulted in maximum leaf length.

Leaf diameter (LD)

The LD was significantly (P < 0.01) affected by urea and NPSB levels (Fig. 2a and b);

however, the no interaction was observed between the two factors (P > 0.05). Increasing urea levels from 0-200 kg/ha resulted in a 33.72% increase in LD (Fig. 2a). This increase in LD, in response to higher urea (46% N) application, could be due to nitrogen's role in promoting stronger vegetative growth over an extended period. This finding aligns with Al-Tabbal et al. (2017), who indicated a decreasing trend in leaf diameter with higher rates of urea, likely due to soil fertility status and environmental conditions. Similarly, Kiros and Nigussie (2018) found the highest LD with nitrogen application. The increase in LD of onions with higher NPSB rates may be attributed to the accessibility of macro and micronutrients. The result is consistent with Gustfson (2010), who reported that phosphorus aids in forming roots and stems, particularly in crops with shallow root systems like onions, thus enhancing the plant's capability to absorb nutrients vital for leaf growth. Fatma et al. (2014) found that sulfur-containing fertilizer positively affected LD. Micronutrient (boron) also plays a crucial role in balancing assimilates in the plant, translocating sugars and carbohydrates to different parts of the plant, which enhances LD in onions.

Bulb diameter (BD)

The blended NPSB (fig. 2b) and urea (fig. 2a) had a significant impact on leaf diameter (P<0.01), however, their interaction was not significant (P>0.05). The maximum BD (7.23 cm) was observed in the application of urea at 200 kg/ha, whiles the smallest value (5.54 cm) was recorded in the nil rates. This resulted in a 30.50% increase BD in comparison to the control (fig. a).

The increase in bulb diameter with the addition of urea may be attributed to the contribution of nitrogen to dry matter production, enhancing bulb size. The association between above-ground dry weight and bulb diameter (r = 0.37*, Table 5) supports this hypothesis. This finding is consistent with Gosa Shura et al. (2022), who indicated a 24.70% maximize in BD with the addition of 92 kg/ha N compared to control. Similarly, Negasi Tekeste et al. (2018) observed a 25% increase in BD with the addition of 138 kg/ha N compared to untreated plots. Furthermore, the application of NPSB at 300 kg/ha resulted in a 31.84% increase in BD in comparison to the control (fig. 2b). Phosphorus enhances carbohydrate content and root growth, ultimately increasing bulb size. Aliyu et al. (2007) highlighted that phosphorus influences BD by affecting the partitioning of assimilates to bulb development. Gosa Shura et al. (2022) found that applying 363 kg NPS ha^{-1} increased BD by 27.33% in comparison to control. Additionally, Shege Getu et al. (2017) reported that onions treated with the highest NPS rates (40:122.6:22.6 kg/ha) formed the largest BD. In contrast, Muluneh Nigatu et al. (2018) reported non-significant effects on bulb diameter with varying NPS fertilizer levels.

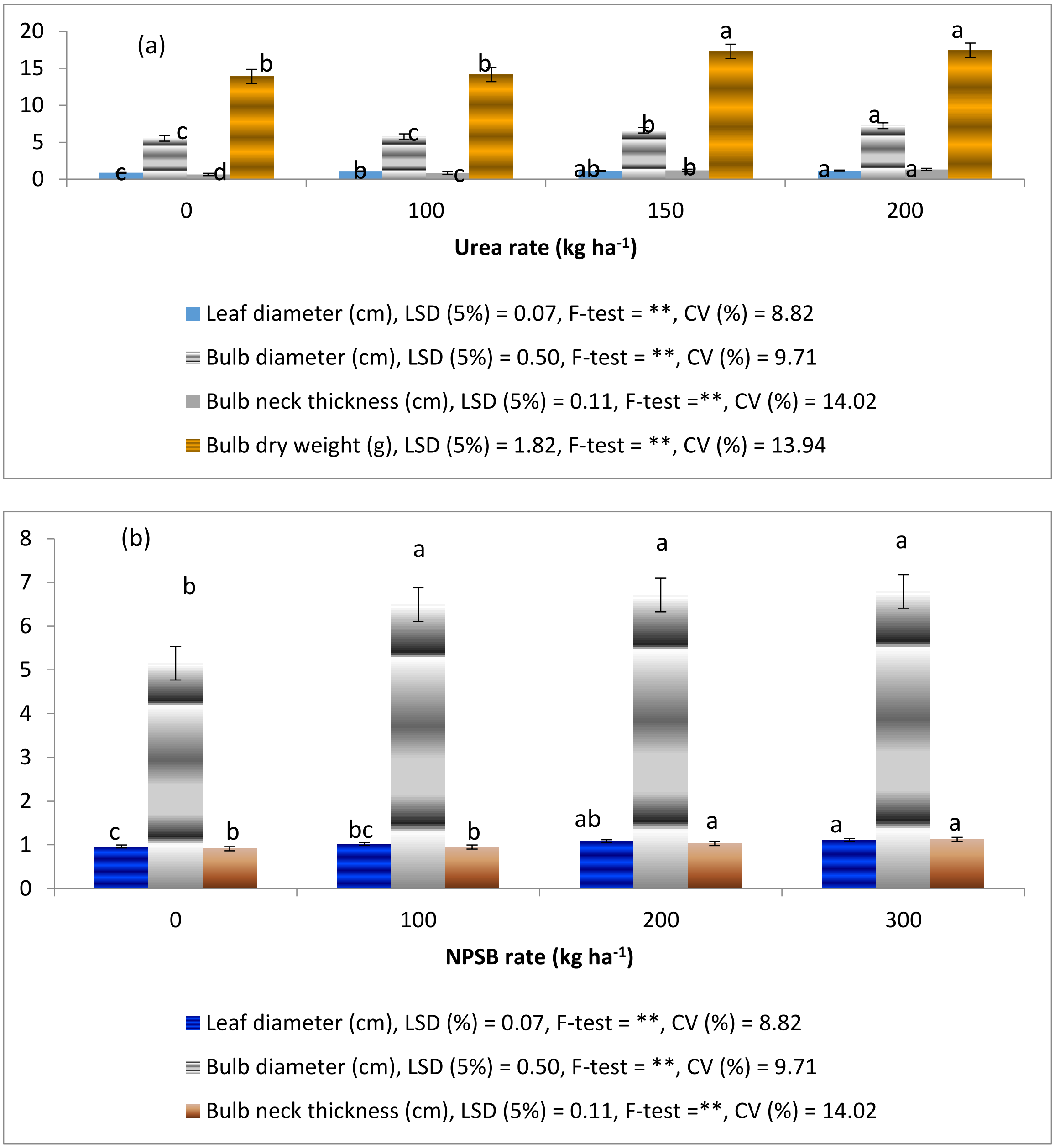

Figure 2: Main effects of urea (a) and NPSB (b) rates on the growth and yield components of onion.

The increase in BD could be due to the manufacturing and partitioning of assimilates in plants with sufficient soil nutrients. This finding aligns with Kelem Muluneh et al. (2024), who reported the widest bulbs (6.12 cm) with NPS applied at 242 kg/ha compared to the control.

Neck diameter of the bulb

The study found that bulb neck diameter was significant impact ($P < 0.01$ influenced by urea (fig. a) and NPSB (fig. b). A notably thicker bulb neck diameter (1.33 cm) was obtained in plots supplied by urea at 200 kg/ha, whereas the thinnest bulb neck (0.65 cm) was recorded in the control plots (fig. a). On the other hand, a thicker bulb neck diameter (1.12 cm) was observed at 300 kg/ha NPSB, while a thinner (0.91 cm) in the control (fig. b). The contribution of urea to plant metabolic processes may enhance bulb diameter and eventually increase bulb neck thickness. Increasing the application rates of NPSB has a significant impact on plant growth and promotes the production of new leaves, contributing to produce thick bulb neck (Al-Tabbal et al., 2017; Fikru Tamiru and Fikreyohannes Gedamu, 2020; Mebrahtom Solomon et al., 2020; Kibebew Fikre et al., 2021; Antene Aweke and Diriba-Shiferaw, 2024). Singh et al. (2018) also reported that higher application rates of NPK and sulfur resulted in increased neck thickness.

Dry matter of bulbs

Significant variation ($P < 0.01$) was observed on dry matter bulbs due to the application of urea fertilizer (fig. 1a). However, NPSB and its interaction with urea had no significant impact on this parameter ($P \geq 0.05$). The control treatment had the lowest bulb dry matter (13.88 g), while the highest value ((17.45 g) resulted from the application of urea at 200 kg/ha (fig. a). The maximum bulb dry matter content with 200 kg ha^{-1} urea application may be attributed to increased photosynthesis, leading to enhanced vegetative growth and higher dry matter partitioning to the harvestable bulbs. The finding aligns with Amare Tesfaw et al. (2013), who reported that well performed plants exhibited higher dry weight. The finding is also in agreement with Al-Tabbal et al. (2017), Tasisa Temesgen (2021), and Chala Kitila et al. (2022). Mandefro Tilahun et al. (2021) pointed out that maximum onion bulb dry matter with the application of 200 kg/ha N combined with 45 kg/ha S. Similarly, Nasreen et al. (2007) found the highest bulb dry matter due to the use of 120 kg/ha N.

Average bulb weight (ABW)

The ABW was significantly ($P < 0.01$) affected by NPSB, urea and NPSB*urea (Table 3). The maximum ABW (110.6 g) was observed when 300 kg/ha NPSB + 200 kg/ha urea. The minimum ABW (38.67 g) was observed in the nil rates of two factors. Applying both fertilizers at their maximum rates resulted in an average bulb weight increase of 186% in contrast to the control treatment (Table 3).

The significant increase in average bulb weight with higher rates of NPSB and urea fertilizers can be attributed to enhanced nutrient uptake, leading to increased vegetative growth and bulb diameter. This hypothesis is supported by association between ABW and PH ($r = 0.60^{**}$) and bulb diameter ($r = 0.65^{**}$). The presence of nitrogen in both blended NPSB and urea, along with phosphorus and sulfur (macronutrients) in blended NPSB and boron in blended NPSB (a micronutrient), likely contributes to plant metabolic processes thereby enhancing bulb weight, as reported by El-Tantawy and El-Beik (2009). Similarly, Muluneh Nigatu et al. (2018) reported that onions treated with a fertilizer at 105:119.6:22 kg/ha N: P_2O_5: S had the highest ABW as compared to the control. Gosa Shura et al. (2022) also indicated maximum bulb weight at NPS levels of 242 to 363 kg/ha and N levels of 0 to 92 kg/ha. Moreover, Bewuket Gashaw (2021) observed an increase in ABW with the application of 57:114:21 kg/ha NPS fertilizer.

Marketable bulb yield (MBY)

The MBY was significantly ($P < 0.01$) affected by blended NPSB, urea and NPSB*urea levels. The maximum MBY (40.58 t/ha) was achieved from 200 kg/ha NPSB + 150 kg/ha urea, while the control treatment yielded the lowest MBY (23.56 t/ha). This represents an impressive 72.24% increase in marketable bulb yield with the specified nutrient combination (Table 3). The existence of S and N in the NPSB likely stimulated enzymatic activity and development of chlorophyll promotes growth and development, which gave rise to higher MBY. In addition, the interactive effect of P, S, and B fertilizers supplemented with urea contributed to the overall plant growth and bulb formation. According to Marschner (1995), the S within the combined fertilizer can be used to increase the availability of plant macronutrients by changing the soil pH level.

The increased MBY from NPSB*urea can be ascribed to enhanced the availability of nutrient and the synthesis chlorophyll in the growing leaves. These nutrients help to a greater photoassimilate manufacturing and capable of translocating to the economic products, at the end boosting marketable yield (Chala Kitila et al., 2022). The correlations among MBY and PH (r = 0.68), LL (r = 0.51**), LD (r = 0.64**), and BD (r = 0.73**) support this assumption. Gosa Shura et al. (2022) reported the highest MBY of onion (47.42 t/ha) at 92 kg/ha N and 242 kg/ha NPS. Similarly, Yadev et al. (2003) reported the maximum MBY of garlic with the blended NPS at 140:122.6:22.6 kg/ha. Negasi Tekeste et al. (2018) observed the maximum MBY of onion at 103.5 kg/ha N * 138 kg/ha P. Chala Kitila et al. (2022) also reported that higher NPS levels correlate with increased MBY. Kibebew Fikre et al. (2021) obtained the maximum MBY (35.1 t/ha) with the application of 125 kg/ha NPSB.

Table 3: Interaction effect of combined NPSB and urea fertilizer rates on onion yield and its components

Urea (kg/ha)	ABW (g)				MBY (t/ha)				TBY (t/ha)			
	NPSB (kg/ha)				NPSB (kg/ha)				NPSB (kg/ha)			
	0	100	200	300	0	100	200	300	0	100	200	300
0	38.67^{h}	80.0^{cd}	93.8^{b}	93.3^{b}	23.56^{h}	27.75^{g}	31.39^{efg}	33.1^{c-f}	25.1^{g}	29.1^{fg}	32.8^{f}	34.4^{c-f}
100	52.5^{fg}	42.6^{gh}	99.1^{ab}	74.27^{d}	28.85^{g}	33.8^{c-f}	34.5^{b-e}	32.6^{def}	29.9^{fg}	34.8^{c-f}	35.7^{cde}	34.1^{def}
150	48.47^{fgh}	84.5^{bc}	70.1^{de}	96.4^{b}	31.9^{efg}	33.8^{c-f}	40.58^{a}	34.9^{b-e}	33.2^{ef}	35.1^{c-f}	41.4^{ab}	36.3^{b-e}
200	61.13^{ef}	96.5^{b}	110.5^{a}	110.6^{a}	30.79^{fg}	37.1^{ab}	36.7^{bc}	39.99^{a}	32.0^{f}	38.6^{abc}	38.7^{a-c}	42.2^{a}
LSD (5%)	12.61				3.73				4.57			
F-test	**				*				**			
CV (%)	9.91				6.88				8.00			

Mean values sharing the same letter in each column are not significantly different at a 5 % probability level.

Total bulb yield (TBY)

The analysis of variance results showed that the TBY of onions was significantly (P < 0.01) affected by NPSB, urea and NPSB*urea fertilizers. The maximum TBY (42.2 t/ha) was achieved with the use of 300 kg/ha NPSB and 200 kg/ha urea in combination form, whereas the minimum

(25.10 t/ha) was observed from the control treatment (Table 3). Consequently, the combined use of NPSB at 300 kg/ha and urea at 200 kg/ha resulted in a considerable increase of TBY by 68% in contrast to the unfertilized plot. This TBY increment could be due to plant nutrients present in NPSB and urea, which make nutrients readily available to the crop, enhancing plant growth and ultimately leading to larger bulbs. This is confirmed by association among TBY and PH (r = 0.70), LF (r = 0.55**), LD (r = 0.64), and BD (r = 0.73**) (Table 5). Yadav et al. (2003) suggested that the increase in MBY could be due to the combined use of blended NPSB with urea, which provides a balanced nutrient supply to the crop.

Considering proper use of nitrogen, phosphorus, sulfur, and boron has significantly affected vegetative growth and chlorophyll synthesis, have enhanced the production of assimilates and TBY of onion (Kelem Muluneh et al., 2024). Similarly, Chala Kitila et al. (2022) observed TBY improvement with the use of NPS in the ranging of 0-200 kg/ha. Additionally, Kelem Muluneh et al. (2024) found the maximum TBY (35.04 t/ha) due to the application of NPS at 242 kg/ha and 0.75% $ZnSO_4$. Muluneh Nigatu et al. (2018) reported an improved TBY of onions with the application of NPS at 105:119.6:22 kg/ha.

Weight loss

Significant variation (P<0.01) was observed in bulb weight loss due to the application of NPSB and urea, but not of NPSB*urea (P>0.05). Weight loss percentage increased with higher rates of NPSB and urea fertilizers, and there was a further rise in weight loss over extended storage periods (Table 4). The highest weight loss percentages in stored onions from plots treated with high rates of either urea or NPSB fertilizer may be due to the larger bulb size, which may have a higher respiration rate.

The effect of blended NPSB can be attributed to phosphate fertilizers enhancing nitrogen use efficiency. Additionally, nitrogen and sulfur have a synergistic effect on nitrogen uptake. The nitrogen in NPSB and urea might cause the development of soft, succulent tissues with high moisture content, making the bulbs lose in their weight (Negasi Tekeste et al., 2017). Banti (2017) observed that increasing N rates from none to maximum levels linearly increased bulb weight loss during storage time. The presence of nitrogen in the bulbs may cause softening, leading to increased weight loss. The result agrees with Tekalign Tsegaw et al. (2012), who pointed out that increasing nitrogen rates enlarged bulb size and subsequently increased the percent weight loss of bulbs.

Table 4: Weight loss of onion bulbs as affected by NPSB and urea fertilizers under ambient conditions

Treatment	Cumulative weight loss (%)							
NPSB (kg/ha)	W_1	W_2	W_3	W_4	W_5	W_6	W_7	W_8
0	5.05^{c}	7.02^{c}	10.56^{c}	17.18^{b}	18.36^{a}	23.89^{c}	23.50^{c}	30.62^{c}
100	5.17^{bc}	7.44^{b}	10.77^{c}	18.10^{a}	18.24^{a}	24.90^{bc}	24.43^{c}	31.97^{bc}
200	5.24^{b}	7.71^{ab}	11.49^{b}	18.18^{a}	20.40^{a}	25.80^{b}	25.82^{b}	33.06^{ab}
300	5.43^{a}	7.99^{a}	12.16^{a}	18.37^{a}	20.62^{a}	26.89^{a}	27.16^{a}	33.83^{a}
LSD (5%)	0.13	0.32	0.45	0.76	2.32	1.08	0.98	1.66
F-test	*	*	*	**	Ns	**	**	*
Urea (kg/ha)								
0	4.87^{d}	5.94^{d}	7.88^{d}	15.43^{d}	16.03^{c}	21.38^{d}	16.98^{d}	24.92^{d}
100	5.16^{c}	6.86^{c}	10.43^{c}	17.22^{c}	19.34^{b}	24.68^{c}	23.63^{c}	32.03^{c}
150	5.30^{b}	8.18^{b}	12.19^{b}	18.93^{b}	19.66^{b}	26.68^{b}	28.31^{b}	35.30^{b}
200	5.57^{a}	9.18^{a}	14.48^{a}	20.25^{a}	22.58^{a}	28.74^{a}	31.98^{a}	37.23^{a}
LSD (5%)	0.13	0.32	0.45	0.76	2.32	1.08	0.98	1.66
F-test	*	*	*	*	*	**	**	**
CV (%)	3.00	5.19	4.89	5.12	14.39	5.11	4.67	6.17

Mean values sharing the same letter in each column are not significantly different at a 5 % probability level; W: represents week.

Bulb sprouting (%)

Significant difference was observed on sprouting of bulbs due to NPSB and urea (P<0.01), however, not in their interaction (P>0.05). The highest sprout percentage (1.58) was observed with urea at 200 kg/ha, whereas the lowest (1.34) in the control at 8 weeks of storage (Fig. 3a). Similarly, the highest sprout percentage (1.84) was achieved with NPSB at 300 kg/ha, whereas the lowest (1.14) in the control at 8 weeks of storage (Fig. 3b). The presence of nitrogen in blended NPSB is likely associated with the relative amount of plant hormones responsible for breaking the dormancy of bulbs. Nitrogen fertilizer contributes to the production of thick-necked bulbs, which in turn increases sprouting during storage because of maximum access of O_2 and moisture to the central growing point. Consistent with this finding, Muluneh Bekele (2018) observed the highest incidence of sprouting (66.11%) due to the maximum nitrogen at 150 kg/ha.

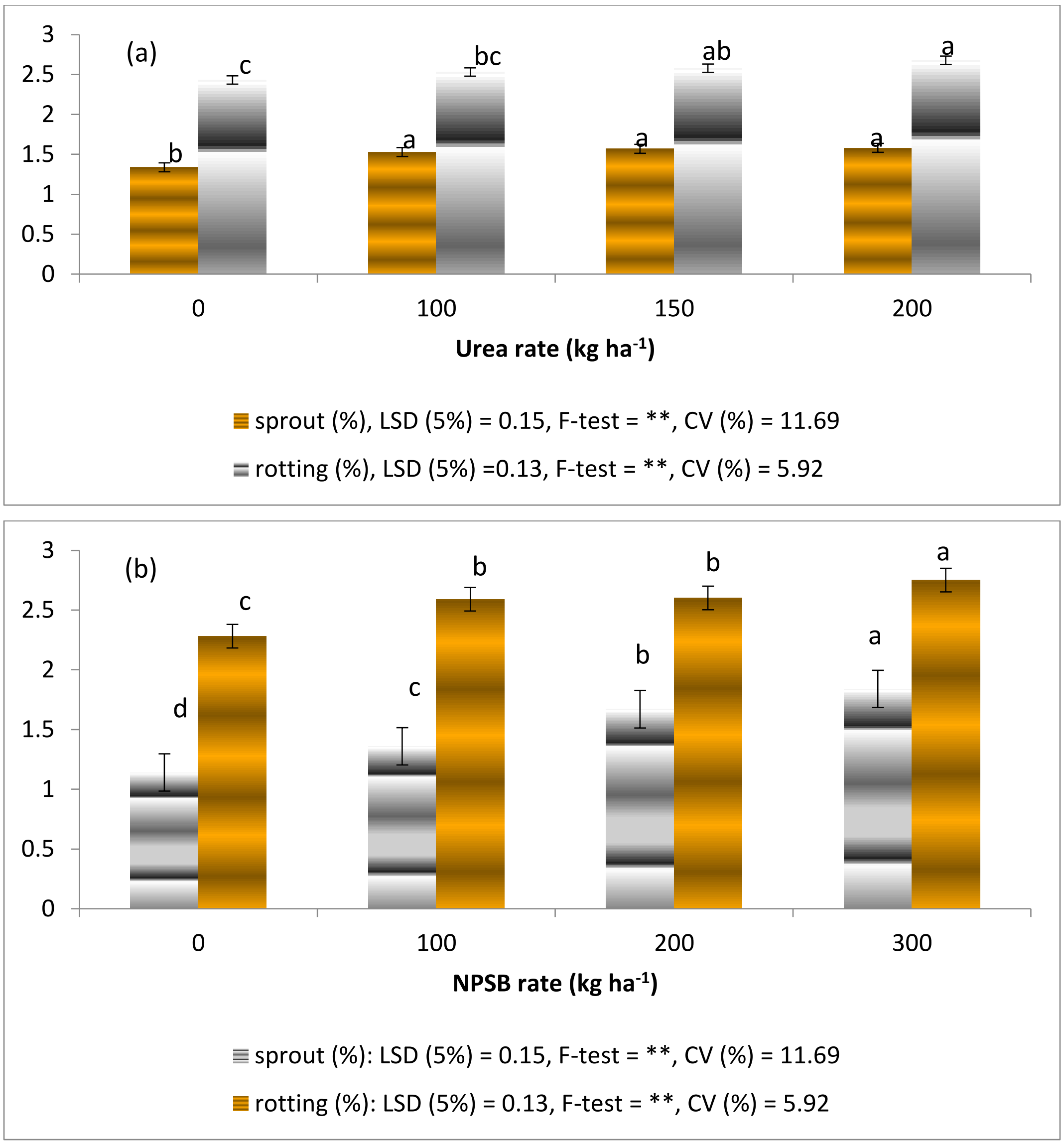

Figure 3: Main effects of urea (a) and NPSB (b) application on the sprouting and rotting of bulbs.

Bulb rotting

The use of urea and NPSB fertilizers had a significant impact on bulb rotting (P<0.01), but had no effect in urea * NPSB (P>0.05). The highest rotting (2.68%) was observed in bulbs harvested from onions grown using urea at 200 kg/ha (Fig. 3a). Similarly, the maximum rotting (2.75%) was obtained with NPSB at 300 kg/ha (Fig. 3b). The greater rotting losses with higher fertilizer rates might be due to increased moisture content and succulent bulbs resulting from N fertilization in both blended and urea fertilizers (Nag, 2018). Muluneh Bekele et al. (2019) also reported that excess nitrogen led to moisture accumulation within the onion bulbs, creating a favorable environment for rot development, which contributed to the higher percentages (Geisseler et al., 2022).

Table 5: Pearson's correlation analysis of onion growth, yield, and related parameters

	PH	DM	LL	LD	BD	BNT	ABW	BDW	MBY	UMBY	TBY	HI
PH	1.00											
DM	0.60**	1.00										
LL	0.47**	0.39*	1.00									
LD	0.61**	0.49**	0.58**	1.00								
BD	0.60**	0.53**	0.52**	0.63**	1.00							
BNT	0.61**	0.53**	0.73**	0.70**	0.63**	1.00						
ABW	0.60**	0.57**	0.28ns	0.48**	0.65**	0.44*	1.00					
BDW	0.37*	0.22ns	0.61**	0.46*	0.37*	0.66**	0.37*	1.00				
MBY	0.68**	0.59**	0.51**	0.64**	0.73**	0.58**	0.57**	0.34*	1.00			
UMBY	0.43*	0.48**	0.50**	0.29*	0.33*	0.49**	0.44*	0.42*	0.39*	1.00		
TBY	0.70**	0.62**	0.55**	0.64**	0.73**	0.61**	0.60**	0.38*	0.99**	-0.52**	1.00	
HI	-0.49*	0.69**	-.59**	-.70**	-.65**	-.65**	-.49**	-0.36*	-.63**	-0.40*	-0.65**	1.00

Relationship between onion growth and yield parameters

The correlation analysis pointed out that the rates of NPSB and urea fertilizers were correlated with onion growth and yield components, except for the harvest index. The correlation characteristics for each onion growth and yield parameter are provided below (Table 5), indicating that blended NPSB and urea fertilizers had a significant and positive effect on all yield and its components of onions. The positive and significant correlations suggest that the marketable yield of onions increased as yield-related parameters improved. This relationship indicates that an increased photosynthetic area, resulting from greater plant height, contributed to enhanced onion yield by producing more assimilates, which were then translocated to the bulbs (Marschner, 1995).

Table 6: Cost-benefit analysis of NPSB and urea for onion productivity

NPSB (kg/ha)	Urea (kg/ha)	Fertilizer cost (Eth-Birr)		Labor cost (Eth-Birr)	TVC (Eth-Birr)	MBY (t/ha)	ADY(t/ha)	GI (Eth-Birr)	NB (Eth-Birr)	MRR (%)
		NPSB	Urea							
0	0.00	0.00	0.00	0.00	0.00	23.56	21.20	1060000	1060000	-
	100	0.00	3530	250	3780	28.85	25.97	1298500	1294720	6209.52
	150	0.00	5295	500	5795	31.91	28.72	1436000	1430205	2744
	200	0.00	7060	750	7810	30.79	27.71	1385500	1377690	D
100	0	3576	0.00	250	3826	27.75	24.975	1248750	1244924	D
	100	3576	3530	750	7856	33.83	30.45	1522500	1514644	4097
	150	3576	5295	1000	9871	33.82	30.44	1522000	1512129	D
	200	3576	7060	1250	11886	37.11	33.40	1670000	1658114	7245
200	0	7152	0.00	750	7902	31.39	28.25	1412500	1404598	D
	100	7152	3530	1250	11932	34.53	31.08	1554000	1542068	D
	150	7152	5295	1500	13947	40.58	36.52	1826000	1812053	7469
	200	7152	7060	1750	15962	36.70	33.03	1651500	1635538	D
300	0	10728	0.00	1250	11978	33.07	29.76	1488000	1476022	D
	100	10728	3530	1750	16008	32.60	29.34	1467000	1450992	D
	150	10728	5295	1500	17523	34.87	31.38	1569000	1551477	6632.67
	200	10728	7060	2250	20038	39.99	35.99	1799500	1779462	9064.89

Note: Farm gate bulb price is 50 Eth-Birr per kg, local selling prices are 15.5 Eth-Birr per kg for NPSB and 14.5 Eth-Birr per kg for urea, and labor costs are 100.00 Eth-Birr Man-Day-1; TVC stands for Total Variable Cost; ADY is Adjusted Yield; GI denotes Gross Income; D indicates Dominated.

Economic Analysis

The analysis indicated that the application of 200 kg/ha NPSB and 150 kg/ha urea in combination form resulted in the highest net This method of fertilizer application generated an additional profit of 752,053 Birr per hectare compared to the control (Table 6). The use of 200 kg/ha NPSB and 150 kg/ha urea not only gave the highest net benefit but also yielded an adjustable marketable bulb output of 38.52 t/ha (Table 6). Based on this cost-benefit analysis, the use of NPSB at 200 kg/ha and urea at 150 kg/ha in combination form can be recommended for onion in the study area.

Conclusion

To achieve the highest potential yield of onions with acceptable quality, the implementation of best cultural practices is crucial. The study showed that using of NPSB and urea fertilizers in combination form resulted in the best outputs of phenological, growth, yield and its components of onions. The maximum MBY (40.58 t/ha), net benefit of 1,812,053 Eth-Birr per hectare, and a MRR (7469%) were achieved using 200 kg/ha NPSB + 150 kg/ha urea. Therefore, using NPSB at 200 kg/ha benefit (NB), amounting to 1,812,053 Ethiopian Birr (Eth-Birr) per hectare, with an acceptable marginal rate of return (MRR) (7469%).

and urea at 150 kg/ha resulted in maximum MBY and economic return although the study recommends further over year and location investigation into its long term sustainability and environmental effects.

Data Availability Statement

All relevant data are within the paper and its supporting information files.

Disclosure

The authors confirm that the content of the manuscript has not been published elsewhere.

Conflicts of Interest

The authors declare no competing interests.

Authors' Contributions

The author (Dr. Biruk Masrie) developed the idea and initiation, edit the draft the proposal, and write the manuscript. The co-author (Dessalegn Shumu) conducted the research, did data collection and analysis. All authors read and approved the final manuscript.

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