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Growth, Yield and Economic Advantage of Onion (*Allium cepa* L.) Varieties in Response to NPSB Fertilizer and Planting Pattern

Anteneh Aweke[1] and G. Diriba-Shiferaw[2*]

[1]Ethiopian Federal Prison Kality Section, Addis Ababa, Ethiopia
[2]Department of Horticulture and Plant Science, College of Agriculture and Environmental Science, Arsi University, P.O. Box 193 Asella, Ethiopia
*Corresponding Author

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ABSTRACT— *Haphazard and low soil fertility, low yielding verities and poor agronomic practices are among the major factors constraining onion production in the central rift valley of Ethiopia. Therefore, a field experiment was conducted in East Showa Zone of Adami Tulu Jido Combolcha district in central rift valley areas at ziway from October 2021 to April 2022 to identify appropriate rate of NPSB fertilizer and planting pattern of onion varieties. The experiment was laid out in split plot design of factorial arrangement in three replications. The main effect of NPSB blended fertilizer rates and varieties (red coach and red king) significantly ($p<0.01$) influenced plant height, leaf length, leaf diameter, leaf number and fresh leaf weight, shoot dry matter per plant, and harvest index. Total dry biomass, bulb diameter, neck diameter, average fresh bulb weight, bulb dry matter, marketable bulb yield, and total bulb yield were significantly ($p<0.01$) influenced only by the main effect of NPSB blended fertilizer rates. In addition, unmarketable bulb yield was statistically significantly affected ($p\geq0.05$) by the blended fertilizer rates and planting pattern. Moreover, days to 90% maturity of onion was affected by the main factor of NPSB fertilizer rate, variety and planting pattern. The non-fertilized plants in the control treatment were inferior in all parameters except unmarketable bulb yield and harvest index. Significantly higher marketable bulb yield (41 t ha^{-1}) and total bulb yield (41.33 t ha^{-1}) was recorded from 300 kg ha^{-1} NPSB blended fertilizer rate applied. Double row planting method and hybrid red coach onion variety had also gave higher growth and yields. The study revealed that the highest net benefit of Birr, 878,894 with lest cost of Birr 148,006 by the combinations of 150 kg blended NPSB ha^{-1} with double row planting method (40cm*20cm*7cm) and red coach variety which can be recommendable for higher marketable bulb yield and economic return of hybrid onion for small scale farmers in the study area. Also, for resource full producers (investors), highest net benefit of Birr 1,205,372 with higher cost (159,628 Birr) by application of 300 kg NPSB ha^{-1} is recommended as a second option. However, the research should be replicated both in season and areas to more verify the recommendations.*

***Keywords*— Onion, NPSB rate, Marketable yield, Planting pattern, Variety**

I. INTRODUCTION

Onion (*Allium cepa* L.) is one of the most important bulb crop cultivated commercially in most parts of the world [FAOSTAT, 2020]. It belongs to the Allium genus of the Amaryllidaceae family (Welbaum, 2015). It is originated in central Asia between Turkmenistan and Afghan where some of its relatives still grow as wild plants. It is a recently introduced crop to Ethiopia from Sudan and then distributed to different parts of the country and now became important vegetable crop for markets and in a daily life of people the country (Nikus and Mulugeta, 2010).

In Ethiopia, 2020/21 during the rainy season 38,952.58 hectares were planted and approximately 346,048.09 tons of bulbs were obtained at an average yield of 8.88 t ha-1 (CSA, 2020/21). But, when compared to other onion producing countries such as the Republic of Korea (66.15 t ha^{-1}), USA (56.13 t ha^{-1}), the Netherlands (51.64 t ha^{-1}), Japan (46.64 t ha^{-1}) and Egypt (36.16 t ha^{-1}) in the production year of 2020 (FAOSTAT, 2020). The low productivity of onion crops in Ethiopia as compared to other onion producing countries is due to low fertility of the soil, inappropriate use of soil macro and micronutrients, diseases, pests, lack of improved varieties, and improper agricultural practices by farmers are the majors (Alemayehu and Jemberie, 2018).

Among the major reasons for low crop productivity in the central rift valley of Ethiopia low soil fertility, low yielding verities and poor agronomic practices can be mentioned. Low soil fertility problem has been repeatedly reported as one of the major factors affecting onion production in the central rift valley of Ethiopia. In Adani Tulu Jido combolcha district the soil organic matter content and the concentration of available micro nutrients such as Zn and B was at low status. The low soil organic matter content such as the federal prison farm soil is (1.570-2.490%) could be low amount of organic material applied to the soil and complete removal of the biomass from the field accompanied with intensive cultivation practice for more than two decades. in addition, the practice of cultivating legume crops as an inter crop and crop rotation system by the farm was poor. the concentration of available Zn (0.19-0.44mg kg^{-1}) was at low states.(Ethiopian Institute of Agricultural Research,2017). The average onion yield in the study area ranged between 7 and 20 tons per hectare while the attainable yield of improved onion variety under research field is about 40 tons per hectare. This is due to low adoption of the recommended onion production package (Dawit *et al*., 2004).

To address these nutrient deficiencies, farmers in the study area have been using DAP and urea fertilizers that only deliver Nitrogen and phosphorous fertilizers for all vegetables including onion to increase crop yields and this did not consider soil fertility status and crop requirement. However, Ethiopian Ministry of Agriculture has recently introduced a new compound fertilizer (NPSB) instead of DAP containing nitrogen (N), phosphorous (P_2O_5), and sulfur (S) and Boron with a ratio of 18.9% N, 37.7% P2 O5, 6.95% S and 0.1%B respectively (Nigatu *et al*., 2018). Hence, sub-optimal levels of these nutrients in the soil adversely affect the yield, quality and storability of onion and shallot bulbs (Messele, 2016). On other hand, overdose application promotes vegetative growth at the expense of bulb yield, wastes resources and affects the environment.

This emphasizes the importance of developing an alternative means to meet the demand of nutrient in plants by using of blending NPSB fertilizers that contains S and boron in addition to the commonly used N and P fertilizers. Different research findings are also showed the importance of Sulfur and boron in onion production in addition to nitrogen and phosphorous. In addition to blanket recommendation of nitrogen and phosphorus, in the Study area of farmers the effect of other fertilizers on growth, yield, and bulb quality of onion are unknown, even though new blended fertilizers such as NPSB are currently available. NPSB constitutes combination of both macro and micro nutrients that improve soil fertility deficiency that can highly influence crop growth, yield and quality of onion.

The response of onion plant to application of fertilizer varies with varieties, rainfall, soils, agronomic practices, expected yield etc. Since this fertilizer is blind it didn’t get any recommendation and Farmers of study area has no information for appropriate rate of the newly introduced blinded NPSB fertilizer for onion production. However, MOA has recommended 100 kg per ha for all blended fertilizers for all crops based on soil fertility information (Molla *et al*., 2020). Yield and quality of dry bulbs can be influenced by cultural practices and growing environments (Geremew *et al*., 2017). So far, research in the country was mainly focused on the identification of superior cultivars of onions and adopting improved management practices for better yield. In addition to this the control of plant spacing is one of the cultural practices to control bulb size, shape and yield. The higher yield and better control of over or under bulb size could be obtained if plants are grown at optimum density.

To optimize onion productivity, full package of information is required. So that, one of the important measures to be taken for increasing the productivity of onion is to determine the optimum amount of fertilizers rates and the availability of high yielding varieties with appropriate agronomic practice that are adapted to the specific growing area is crucial. Hence, there is a need to develop a site-specific recommendation on the fertilizer rates, varieties and planting method to increase production and productivity of onion. So this study is aimed to evaluate the effect of different rates of blended NPSB fertilizer on single and double rows planting patterns on growth and yield attributes of onion varieties under irrigation conditions of smallholder farming system of Adami Tulu Jido Combolcha in central rift valley areas of East Showa Zone.

II. MATERIALS AND METHODS

2.1. Description of the Study Area

The experiment was conducted at Ziway federal prison farm in Adami Tulu Jido Combolcha district from October 2021 to April 2022 under full irrigation conditions. It is located in the mid rift valley (MRV), 160km South of Addis Ababa on Hawassa road. It lies at a latitude of 7°9'N and 38°7'E longitude. It has an altitude of 1650 m.a.s.l. and a bimodal unevenly distributed average annual rainfall of 760 mm. Clay Loam texture soil with mean sand silt clay percentage of 31.3, 41.3 and 27.5 respectively. Generally have a Clay loam surface soil texture with an optimum pore space and bulk density which is an indication of less compaction, drainage and aeration. The pH value of soil in the farm was 8.39, which showed strongly alkaline (Tekalign, 1991). Generally, the laboratory analysis results proved that the soil was suitable for the production of onion.

2.2. Experimental Materials

Two onion varieties namely: red coach and red king (hybrid) that are most widely cultivated in the study area (Table 1) and NPSB fertilizer was used as experimental materials. NPSB blended fertilizer contained 18% N, 38% P_2O_5, 7% S and 0.1% B in its chemical composition (Table 2).

Table 1. Description of onion varieties used for the study

	Varieties	Elevation	RF	Day to mature	Bulb color	Productivity (t ha^{-1})	
						Research field	Farmers' field
1	Red coach	700-2200 m.a.s.l.	350-550ml	107	Red	50.4	42.0
2	Red king	700-2200 masl	350-550ml	112	Red	55.0	46.0

Source: from Awash Melkasa research center and minister of agriculture

2.3. Treatments and Experimental Design

The improved hybrid seeds of two onion varieties of red coach and red king and five levels of NPSB fertilizer rates (0, 75, 150, 225, 300 kg ha^{-1}) were arranged on single and double rows planting patterns of having a spacing of 40 cm between double rows, 20 cm in single rows and 7 cm spacing between plants were used as treatments to carry out the experiment. Factorial combinations of two varieties of onion and five NPSB rates were replicated within the two planting patterns which were used for the experiment. This was laid out in split plot design in three replications. Which was made 20 treatment combinations and fertilizer composition is sated in the below table. These ten treatments were randomly distributed within two main plots (single row planting pattern) and also there were similar arrangement with in second main plot (double row planting pattern).

Table 2. Rate and composition of fertilizer used for the study

No	Blended NPS Fertilizer rate (kg ha^{-1})	N%	P_2O_5%	S%	B%
1	0 kg NPSB	-	-	-	-
2	75 kg NPSB	13.5	28.50	5.25	0.075
3	150 kg NPSB	27	57.00	10.50	0.150
4	225 kg NPSB	40.50	85.50	15.75	0.225
5	300 kg NPSB	54.00	114.00	21.00	0.300

Blended NPSB fertilizer that contains N: P2O5: S: B (18N-38P2O5-7 S-0.1 B)

2.4. Experimental Procedures and Crop Management

The experimental field consisted of 24m width and 24.5 m length amounting to a total gross area of 588 m^2. The size of each unit plot was 3.0 m × 2.0 m (6 m^2), having a spacing of 40 cm between double rows, 20 cm in single rows and 7 cm between plants within the row. Each plot would have 5 rows in double rows and 10 rows in single rows of plants from which one outer most row on each side of a plot and four plants (28 cm) on each end of rows was considered as border. The three central rows were used for data collection to avoid possible border effects. The blocks were separated by a 1.5m wide open space whereas the plots within a block were separated by a 1m wide space to provide appropriate agronomic management. NPSB fertilizer was used as a source of mineral nutrients.

The experimental field was ploughed two times by tractor and leveled manually according to the design and also field layout was made. Each treatment was assigned randomly to the experimental units within a block. All important cultural practices were undertaken based on the recommendations made for the onion crop (EARO, 2004). The experiment was conducted under furrow irrigation conditions. NPSB fertilizer of full doses which varies depending on treatments was applied as side band placement at transplanting time. The remained urea was applied after 35 days after transplanting was done that facilitate the vegetative growth of onion (EARO, 2004).

2.5. Soil Sampling and Analysis

Separate core soil samples were taken from each plot for the Determination of soil bulk density. The representative composite soil samples was taken in a zigzag pattern from the experimental plots at the depth of up to 20 cm using an auger before planting and fertilizer application. The collected soil sample was brought for laboratory analysis. The soil samples were air dried, crushed and passed through a 2 mm sieve and analyzed for the selected soil physco-chemical properties, such as particle size distribution, particle density, porosity, soil reaction, electrical conductivity, total nitrogen, available phosphorous and sulfur, exchangeable cations (Ca, Mg, K, and Na),organic carbon/matter , cation exchange capacity, calcium carbonate and extractable Micronutrients(Fe, Mn, Zn,Co and B) following standard laboratory analytical procedures.

Soil textural class was determined by Bouyoucos Hydrometer Method (Day, 1965). Soil pH was determined in 1:2.5 soils: water ratio using a glass electrode attached to a digital pH meter (Walkley and Balck, 1934). Organic carbon (%) was determined by wet digestion method (Walkley and Black, 1934); then the organic matter (%) was calculated by multiplying the OC% by factor 1.724. Cation Exchange Capacity (Cmol kg^{-1} soil), of the soil sample first was leached using 1 M ammonium acetate, washed with ethanol and the adsorbed ammonium was replaced by sodium (Na). Then, the CEC was determined titrimetrically by distillation of ammonia that was displaced by Na (Sahlemedhin and Taye, 2000). Exchangeable bases (potassium, magnesium, sodium, and calcium) were as determined by Melich-3 methods (Mehlich, 1984).

2.6. Data collected

Data on growth, yield and yield components of onion were recorded from the four central single and double rows plants which were selected randomly in each plot as specified in each plant characters below. However, data for phonology of crop was collected from five sample plants per plot. Days to maturity was recorded as the actual number of days from the date of transplanting until more than 90% of plants shows neck fall (EARO, 2004). Average plant height of ten randomly pre-tagged plants from the net plot area was measured at 90% maturity from the base of the plant to the top of the main shoot using meter. Average leaf number per plant of ten randomly pre-tagged plants from the net plot area was counted 92 days after transplanting at 90% maturity stage from the base of the plant to the top of the main shoot. The diameter (cm) of leaves at three different places of the leaves was measured from ten randomly selected plants using veneer caliper. Leaf length (cm) was measured at physiological maturity from the sheath to tip of the leaf from the ten leaves of the representative plants which was used to count the number of leaves per plant using a ruler. Fresh leaf weight (g) per plant was measured from an average of ten randomly pre-tagged plants from the middle rows per plot after harvested. Shoot dry matter (g) refers to the above ground biomass of the plant, which was oven dried at the temperature of 65^{0}C until a constant weight was obtained. The aboveground biomass was harvested by cutting the plant at the crown part and the shoot dry matter was determined and expressed in gram at harvest. Dry total biomass (g) was determined by summation of the shoot and bulb dry matter weights of sample plants.

The mean bulb diameter (cm) of samples bulbs based on total number of plants available on the plot as data was recorded per plot of all the treatment was measured at the maximum wider portion of matured bulbs using calipers. The average neck width (cm) of ten randomly taken mature bulbs was measured by using a veneer caliper after harvest. The average fresh weight (g) of ten randomly taken mature bulbs was measured by using sensitive balance. Bulbs dry matter (g) was recorded from five bulbs taken randomly from ten plants from each plot for shoot dry matter and chopped into small 1-2 cm cubes, mixed thoroughly, and two sub-samples each weighing 200 grams was weighed. The exact weight of each sub-sample was determined and recorded as fresh weight. Each sub-sample was placed in a paper bag and put in an oven until constant dry matter was attained. Each sub-sample was then immediately weighed and recorded as dry matter yield.

Bulb size distribution of marketable bulbs: Based on the weight of bulbs from categories of bulb size for small (20 - 50 g), medium (50 – 100 g), large (100 -160 g), and oversized (> 160 g) was recorded per net plot and converted to t ha^{-1} as determined by Lemma and Shimeles (2003). Marketable bulb yield (t ha^{-1}) referred to the weight of healthy and marketable bulbs that range from 20 g to 160 g in weight. Bulbs below 20 g in weight were considered too small to be marketed whereas those above 160 g were considered oversized according to Lemma and Shimeles (2003). This parameter was determined from the net plot at final harvest. Unmarketable bulb yield (t ha^{-1}): The total weight of unmarketable bulbs that are under sized (< 20 g), diseased, decayed and bulbs from plants with physiological disorder such as thick neck and split was measured from a net plot at final harvest. Total bulb yield (t ha^{-1}) was measured from the total harvest of net plot as a sum weight of marketable and unmarketable yields that was measured in kg per plot and finally converted into t ha^{-1}. Harvest index was expressed as the ratio of total bulb dry weight to the total biomass dry weight multiplied by 100%

2.7. Data Analysis

All the collected data were first checked for fitting the analysis of variance (ANOVA) and examine for normality assumptions. Then, all data were subjected to ANOVA using SAS 9.3 version (SAS, 2012). Whenever, the ANOVA shows significant differences between treatments, mean comparison and separation was done by using Least Significant Difference (LSD) test at a 5% level of significance.

2.8. Partial Economic Analysis

An economic analysis was done using partial budget procedure described by CIMMYT (1988). Labor costs involved for application of NPSB and N fertilizer rates was recorded and used for analysis. The time price of bulb yield and fertilizers were valued at an average open market price at local town. The net returns (benefits) and other economic analysis were based on the formula developed by CIMMYT (1988) and given as follows: Unadjusted Total bulb yield (UTBY) (t ha^{-1}): the average total bulb yield of each treatment. Adjusted Total bulb yield (ATBY) (t ha^{-1}): the average total bulb yield adjusted downward by a 10% to reflect the difference between the experimental yield and yield of farmers. Gross field benefit (GFB) (ETB ha^{-1}): was computed by multiplying field/farm gate price that farmers received for the crop when they sell it as adjusted yield. GFB = ATBY× field/farm gate price for the crop. Total variable cost (TVC) (ETB ha^{-1}): was calculated by summing up the costs that vary, including the cost of NPSB fertilizer and Urea as N source fertilizer at the time of planting (October, 2021), and labor cost for application of fertilizers. The costs of other inputs and production practices such as labor cost for land preparation, planting, weeding, harvesting and threshing were considered the same for all treatments or plots. Net benefit (NB) (ETB ha^{-1}): was calculated by subtracting the total variable costs (TVC) from gross field benefits (GFB) for each treatment as NB = GFB – TVC. Marginal rate of return (MRR) (%): was calculated by dividing change in net benefit (ΔNB) by change in total variable cost (ΔTVC) as:

$$\mathrm{MRR} = \frac{\Delta \mathrm{NB}}{\Delta \mathrm{TVC}} \times 100$$

The dominance analysis procedure as described in CIMMYT (1988) was used to select potentially profitable treatments from the range that was tested. The discarded and selected treatments using the technique were referred to as dominated and non-dominated treatments, respectively. Identification of a candidate recommendation was from among the non-dominated treatments. That was the treatment which gives the highest net return and a marginal rate of return greater than the minimum acceptable to farmers (100%) was considered for the recommendation.

III. RESULTS AND DISCUSSION

3.1. Physico-Chemical Properties of the Experimental Soil

The results of the soil analysis are presented in Table 3. The soils had clay loam texture (clay 27.5, silt 41.3 and sand 31.3) indicating that the soils had relatively higher water holding capacity. The mean pH value was 8.39, which is strongly alkaline condition according to Tekalign (1991) ratings. The optimum pH for onion production ranges between 6 and 8 (Nikus and Mulugeta, 2010). Accordingly, the pH of the soil was conducive for onion production. The Total N content value was 0.200 this indicating that high in total N status (Tekaling, 1991). While the organic matter content was 2.45, this indicated that the soil was low in organic matter content. In order to increase organic matter and total N content of the soil introduction of leguminous species in to the cropping system has to be exercised.

The organic carbons content (1.419) of the soil was medium according to the rating of Tekalign (1991). This shows that the soil was medium in supplying organic carbon for soil biota and also as a source of mineralized nitrogen for uptake mineral nitrogen by crops (Hazelton and Murphy, 2007). Hence, it requires application of nitrogen for onion production. The value of C: N ratio 7.1is moderate range indicating that moderate rate of mineralization and oxidation of organic matter (Mohammad *et al.*, 2011). According to Olsen *et al.* (1954), the soil of the experimental site was medium in available phosphorus (9.8). This shows that application of external source of phosphorus is important for growing onions. The total cation exchange capacity of the testing site was high (29.8) (Landon, 1991). According to the criteria developed by Jones (2003) the concentration of available Fe (6.11) and Mn (6.88) were generally adequate. However, the concentration of available Zn (0.19) and Cu (0.31), B (1.15) was at low, marginal and medium status respectively (Table3). Therefore, extractable Cu for the soil is within the critical limit for crop production. but, the soil are deficient in Zn (far below 0.5 mg kg^{-1}) recommended rate of Zn fertilizer or any management practice that boost the soil Zn status should be exercised for optimum onion crop production.

Table 3. Physical and Chemical characteristics of the experimental soil before planting

Soil Properties	Values	Rating	Source
Particle size distribution (%)			
Clay (%)	27.5		
Silt (%)	41.3	High	
Sand (%)	31.3	Low	
Soil textural class		clay loam	Hazelton and Murphy
pH	8.39	Strongly alkaline	Tekalign (1991)
Electrical conductivity (ms m^{-1})	0.86		
Total nitrogen (%)	0.200	High	Tekalign (1991
Total available phosphorus (mg kg$^{-1)}$	9.8	medium	Olsen et al. (1954)
Available sulfur (mg P_2O_5 kg^{-1} soil)	23.23	Sufficient	Hazelton and Murphy (2007)
Cation exchange capacity(meg 100g^{-1})	29.8	High	Hazelton and Murphy (2007)
Organic carbon (%)	1.419	medium	Tekalign (1991)
Organic matter (%)	2.45	medium	Tekalign (1991)
Extractable micro-nutrients (mg kg^{-1})			
Zn	0.19	Low	Jones (2003)
Fe	6.11	medium	Fe
Mn	6.88	medium	Jones (2003)
Cu	0.31	marginal	Jones (2003)
B	1.12	medium	Jones (2003)

3.2. Phonology and Growth Parameters as influenced by Fertilizer and Planting Pattern

3.2.1. Plant height, leaf length, leaf number, leaf diameter and days to maturity

Result from the analysis of variance revealed that the main effects of NPSB fertilizer rate and variety significantly ($P < 0.01$) influenced plant height, leaf length, leaf number, leaf diameter and days to maturity of onion. However, the main effect of planting pattern (except days to maturity) and its interaction with NPSB blended fertilizer rate and variety did not influence them statistically ($p>0.05$). This might be due to there is no variability between double and single rows planting (Table 4).

Increasing the rate of NPSB from 0 to 300 kg ha^{-1} significantly increased the height, leaf length and leaf number of onion. The highest height (63.83cm), leaf length (52.8 cm), leaf number (14.74), leaf diameter (1.49 cm) and days to maturity (109) was obtained from NPSB fertilizer rate of 300 kg ha^{-1}. In contrast, the nil NPSB fertilizer rate combined with the variety produced the lowest plant height (45.84cm), leaf length (35.9cm), leaf number (8.41), leaf diameter (0.85cm) and days to maturity (98.33). Thus, the mean height, leaf length and leaf number of onion treated with NPSB at the rate of 300 kg ha^{-1} exceeded the height, leaf length, leaf number, leaf diameter and days to maturity of onion plants treated with nil and 75, 150, and 225kg NPSB ha^{-1} by about 39, 16, 11, 7%; 32,14.4,10.6,7.4%; 42.9, 28.7,19.27,10.3%; 42.95, 27.52, 13.42, 8.72% and 9.8, 7.6, 4.2, 2.14%, respectively (Table 4). This result was in agreement with many scholars like (Hamady, 2017) who reported that increasing phosphorus fertilizer rates markedly increased foliage height of onion. Gateri *et al.* (2018) reported that Boron at different doses had remarkable effects on the production of leaf, plant height, root numbers, germination percentage, and quality of onion seed. Sulfur is important in the building block of protein and a key ingredient in the formation of chlorophyll. This is in agreement with the finding of Bloem *et al.* (2005) who observed that onion is a sulfur loving plant that is required for proper growth and bulb development. Boron is also an essential micronutrient that is necessary for normal cell division, nitrogen metabolism, protein formation, and phosphorus uptake. Assefa *et al.* (2013) had reported that plant height was increased with an increased in the combined application of N, P, S, and Zn fertilizers.

Moreover, Molla *et al.* (2020) also found an increasing trend of plant height and leaf length with increasing rates of blended NPSB fertilizer levels. In contrast to this finding Tekeste *et al.* (2018) reported non-significant results in plant height with increasing the levels of phosphorus-containing fertilizer like NPS. Similarly, Nigatu *et al.* (2018) reported the longest leaf length from the highest NPS fertilizer levels. However, Messele (2016) reported non-significant result in leaf length with increasing phosphorus fertilizer of onion crop. Similarly, Nigatu *et al.* (2018) reported the highest number of leaves per plant due to the combined application of 105:92:16.95 NPS. However, this result is in contrary to the findings of Tilahun *et al.* (2021) who reported the highest leaf number from the combined application of 200 kg ha^{-1} N and 45 kg ha^{-1} of Sulfur while the shortest was recorded from 100 kg ha^{-1} of N with 0 kg ha^{-1} sulfur. The delayed maturity could be related with the effect of nitrogen in extending the vegetative growth period of plants. On the other hand, early maturation at the control level may be due to insufficient nutrient intake that slows plant growth; thus it entered the fertility phase and matured earlier. This is in line with Muluneh (2016) who reported the highest (142 days) of days to physiological maturity recorded from the plot supplied with136.5:119.6:22 kg ha-1 N: P2O5:S fertilizer rate. This study is also in conformity with the findings of Asefa (2017) who reported that increasing application rate of NPS resulted in highest maturity dates of garlic. The study of Van Burg (1983) also indicates increasing application of Nitrogen encourage branching, number and size of leaves, and decrease leaf senescence, thus increasing the leaf area that lead to delayed days to maturity of the plant.

Planting patterns (double and single rows) did not statistically differ in terms of mean values except days to maturity (Table 4). A higher day to maturity was recorded from double row as compared to single row planting pattern. However, onion varieties were significantly differed the mean values of plant height, leaf length, leaf number, leaf diameter and day to maturity; higher mean values were recorded from red coach as compared to red king variety in all parameters (Table 4). This indicated that there are genetically differences in phenology and growth of onion varieties.

3.2.2. Fresh leaf weight, shoots dry matter (g) and total dry biomass (g) per plant

Result from the analysis of variance revealed that the main effects of NPSB fertilizer rate and variety highly significantly ($p<0.01$) influenced fresh leaf weight, shoots dry matter and total dry biomass of onion except total dry biomass by variety. However, the main effect of planting pattern and its interaction with NPSB blended fertilizer rate and variety did not significantly ($p>0.05$) influence leaf weight, shoots dry matter per plant and total dry biomass (Table 5).

Increasing the rate of NPSB from 0 to 300kg ha^{-1} significantly increased the fresh leaf weight, shoot dry matter of onion and total dry biomass. The highest fresh leaf weight (72.8g), shoot dry matter (8.48g) and total dry biomass (19.79 g) was obtained from NPSB rate of 300 kg ha^{-1}. In contrast, the nil NPSB fertilizer rate produced the lowest leaf weight (34.13g), shoot dry matter (2.79g) and total dry biomass (7.98g). Thus, the mean fresh leaf weight, shoot dry matter and total dry biomass of onion treated with NPSB at the rate of 300 kg ha^{-1} exceeded the fresh leaf weight, shoot dry matter and total dry biomass of onion plants treated with nil and 75,150,225 kg NPSB ha^{-1} by about 53.1,34.5,21,8.9%; 67.1,51.7,39,15.9%; and 59.7,45.6,32.7,12.7%, respectively (Table 5). The result obtained could be due to integrated application of NPSB fertilizers which contains rich source of vital macronutrients and micronutrients which enhance plant vegetative growth and development that leads to increase plant above ground fresh biomass. The present finding is in line with Bewuket *et al.* (2017) who reported the highest overall fresh biomass of garlic at application of 46 kg ha-1 N and P2O5 + 5 t ha^{-1} vermicompost which contains rich source rich source of vital macronutrients (N, P, K, Ca and Mg) and micronutrients (Fe, Mo, Zn, and Cu). The increment in vegetative growth and dry weight of plant organs may be due to direct effect of sulphur on soil properties which decrease pH values thereby enhance availability of other essential nutrients, plant metabolism, increased photosynthetic rate, and free amino acids (Abd El-Kader *et al.*, 2007). Similar result was obtained by Shege *et al.* (2017) who reported the maximum above ground dry biomass from the application of (105:122.6:22.6) NPS fertilizer which promotes the growth and development of garlic.

Table 4. Main effect of fertilizer rates, row types and varieties on growth parameters of onion

Treatment	**PH**	**LL**	**LN**	**LD**	**DM**
Fertilizer (kg ha^{-1})					
0	45.84d	35.90d	8.41d	0.85d	98.33e
75	55.02c	45.21c	10.51c	1.08c	100.67d
150	57.51bc	47.23bc	11.90bc	1.29b	104.38c
225	59.48b	48.92b	13.22b	1.36ab	106.67b
300	63.83a	52.80a	14.74a	1.49a	109.00a
LSD(0.05)	4.22	3.70	1.40	0.14	0.83
Planting pattern					
Double row	57.16a	46.73a	11.96a	1.29a	104.13a
Single row	55.51a	45.29a	11.56a	1.19a	103.47b
LSD(0.05)	2.67	2.34	0.89	0.09	0.52
Varieties					
Red coach	57.85a	47.35a	12.24a	1.26a	108.33a
Red king	54.82b	44.68b	11.27b	1.54b	99.27b
LSD(0.05)	2.67	2.34	0.89	0.09	0.52
CV(%)	9.07	9.75	14.47	14.16	0.96

PH- plant height; LL- leaf length; LD- leaf diameter; LN- leaf number; DM- days to maturity; Means with the same letter(s) within a column are not significantly different from each other at a 5% level of probability.

Table 5. Main effect of NPSB fertilizer rates, row types and varieties on growth parameters

Treatment	**FLW**	**SDM**	**TDB**
Fertilizer(kg ha^{-1})			
0	34.13e	2.79e	7.98e
75	47.7d	4.10d	10.77d
150	57.53c	5.17c	13.32c
225	66.31b	7.13b	17.28b
300	72.80a	8.48a	19.79a
LSD(0.05)	5.98	0.57	1.69
Planting pattern			
Double row	56.51a	5.65a	14.04a
Single row	54.88a	5.42a	13.62a
LSD(0.05)	3.78	0.36	1.07
Variety			
Red coach	57.74a	5.80a	14.34a
Red king	53.65b	5.28b	13.32a
LSD(0.05)	3.78	0.36	1.07
CV	13.02	12.42	14.77

FLW- fresh leaf weight; SDM- shoots dry matter; TDB- total dry biomass. Means with the same letter(s) within a column are not significantly different from each other at a 5% level of probability.

The increased total dry biomass yield might be due to the role of nitrogen and sulfur which plays crucial role in plant physiological and metabolic reaction to enhance synthesis of chlorophyll that produce photosynthate material in plant leaf that improves the cell division, growth and development which increase dry weight in leaves and bulbs. In accordance with this finding Yayeh *et al.* (2017) also reported the highest total dry biomass at the same levels of NPS fertilizer. However, Nigatu *et al*. (2018) and Anbes *et al*. (2018) reported non-significant results in total dry biomass of onion by the application of less than 136.5 kg N ha^{-1} within the blended NPS.

Planting patterns (double and single rows) did not statistically differ in terms of mean values (Table 5). Onion varieties were significantly affected the mean values of fresh leaf weight and shoots dry matter; however, did not influence total dry biomass. Higher mean values for fresh leaf weight and shoots dry matter was recorded from red coach as compared to red king variety (Table 5). This indicated that there are genetically differences in weight and dry matter accumulation of onion varieties.

3.3. Yield and Yield Components as influenced by Fertilizer and Planting Pattern

3.3.1. Bulb and neck diameters (cm), fresh and dry matter bulbs weights (g)

The main effects of blended NPSB fertilize significantly ($p<0.01$) influenced the bulb diameter, neck diameter, fresh bulb weight and bulb dry matter of onion. However, the main effect of planting pattern, variety and their interaction with NPSB blended fertilizer rate did not significantly ($p>0.05$) influence them (Table 6). Increasing the rate of NPSB from nil to 300 kg ha^{-1} significantly increased the bulb and neck diameters, fresh and dry matter of bulb weights of onion. The increase in blended NPSB fertilizer level significantly increases the bulb and neck diameters, and fresh and dry matter weights from the lowest value of 3.54cm, 0.69cm, 68.54g and 5.19g at the control to the highest value of 6.89 cm, 1.31cm, 109.06g and 11.31g at 300 kg ha^{-1} (Table 6). Current study implied that, the increment application rates of blended NPSB fertilizers provides tremendous effect on overall plant growth and encourages the growth of new shoots/leaves and increased bulb and neck thickness and fresh and dry matter weights. This could be attributed to undertaking of plant growth and formation of a greater number of leaves per plant that increases their thickness and bulbs weights (Bangali *et al*., 2012). In line with the present observation, Singh *et al.* (2018) reported an increase in application of NPK and sulphur which result in an increase in neck thickness and shell thickness which could be attributed to increase in uptake of NPK and sulphur by the crop thereby it enhances the synthesis and translocation of photosynthates to the bulbs and the storage organs of the onion, resulting in higher dry matter accumulation in cover and neck portion of the bulbs. The other findings also stated that, Combinations of N, P, S, and Zn fertilizers played a positive role in the development of onion bulb diameter. Yet, the application of compost and combinations of N, P, and S to soils somehow increased the bulb diameter (Assefa *et al*., 2015). Yayeh *et al.* (2017) also stated that onions supplied with the highest NPS rates (40:122.6:22.6) produced the biggest bulb diameter. However, Nigatu *et al.* (2018) reported non-significant results on bulb diameter of onion due to levels of NPS fertilizer.

The highest bulbs fresh and dry matter weights obtained from current study could be from the positive effect of blended NPSB fertilizers which resulted in releasing their higher nutrient content in the soil which is advantageous in increasing onion bulb weight and eventually reflected in maximizing bulb yield parameters. This might be due to the increasing rate of nutrients which play beneficial roles in enhancing onion productivity through the production of more assimilates and allocation to the bulbs. Nigatu *et al.* (2018) also reported maximum bulb weight in the range of 105:119.6:22 to 136.5:119.6:22 kg ha^{-1} of NPS fertilizer. Similarly, Bewuket (2017) reported the highest average bulb weight of onion from 57:114:21 kg ha^{-1} NPS fertilizer. The results of fresh weight of bulbs are also in agreement with the findings of Satbir *et al.* (1989). They stated that fresh weight of bulb significantly increased by using Zn and B.

3.3.2. Total and marketable bulb yield (t ha^{-1})

The main effects of NPSB fertilizer rate significantly ($p<0.01$) influenced total and marketable bulb yields of onion. However, the main effect of planting patter, variety and their interaction with NPSB blended fertilizer rate did not significantly ($p>0.05$) influence the above parameters. This may be due to there is no genetic variability between varieties and planting pattern (Table 7). Increasing the rate of NPSB from nil to 300kg ha^{-1} significantly increased the total and marketable bulb yields of onion. The highest total bulb yield (41.33 t ha^{-1}) and marketable bulb yield (41 t ha^{-1}) was obtained from NPSB rate of 300 kg ha^{-1}. In contrast, the nil NPSB fertilizer rates produced the lowest total bulb yield (13.27 t ha^{-1}) and marketable bulb yield (12.53 t ha^{-1}). Thus, the mean total and marketable bulb yields of onion treated with NPSB at the rate of 300 kg ha^{-1} exceeded the onion plants treated with nil and 75,150,225 kg NPSB ha^{-1} by about 68, 48, 27, 14% and 69, 49, 27, 14%, respectively (Table 7). The increment of total and marketable bulb yields may be due to an increase in bulb size and bulb weight by the applied NPSB fertilizer which may increase photosynthesis, and subsequently, enhanced growth and expansion of vegetative growth as a whole, and ultimately significantly higher carbohydrate to the bulbs at maturity. The result agrees with many researchers who reported that application of Nitrogen, Phosphorous, Sulfur, and Boron in their single and blended form have a significant effect on the growth and yield parameters of onion (Gessesew *et al*., 2015; Alemayehu, 2018; Negatu *et al*., 2018). Other findings also stated that almost all the yield and yield parameters studied were significantly affected by different combinations of N, P, S, and Zn fertilizers and compost. Maximum yield was obtained from plots that received combined fertilizers of N, P, S, and Zn. Therefore, combined application of nitrogen, phosphorous, sulfur, and zinc together at the rate of 130, 20, 21 and 15 kg ha^{-1}, respectively is found to be the most suitable combination and dose for maximum growth and yield of onion (Assefa *et al.*, 2015). Manna (2014) and Zaman *et al*. (2011) indicated that the application of Boron and Sulfur increased the yield of onion and stimulated the enzymatic actions as well as chlorophyll formation, which promote the growth and development of plants. This is also in line with the result obtained due the interaction effects of NPSB blended fertilizer rate and varieties (Bombe and Adama red) which had significantly ($p<0.05$) influenced the total bulb yield per hectare of onion (Molla *et al*., 2020). The findings of Tilahun *et al.* (2021) who reported an increase in bulb dry weight of onion with the application of 200 kg ha^{-1} nitrogen and 45 kg ha^{-1} sulfur.

Table 6. Main effect of NPSB fertilizer rates, planting pattern and varieties on yield components of onion

Treatment	BD	ND	AFBW	BDM
Fertilizer(kg ha^{-1})				
0	3.54d	0.69d	68.54d	5.19e
75	4.61c	0.88c	81.43c	6.67d
150	5.57b	1.08b	93.27b	8.15c
225	6.20b	1.18b	101.85ab	10.15b
300	6.89a	1.31a	109.06a	11.31a
LSD(0.05)	0.64	0.12	11.84	1.14
Planting pattern				
Double row	5.52a	1.06a	92.05a	8.39a
Single row	5.21a	0.99a	89.61a	8.2a
LSD(0.05)	0.40	0.08	7.49	0.72
Varieties				
Red coach	5.53a	1.06a	93.36a	8.54a
Red king	5.19a	0.99a	88.29a	8.04a
LSD(0.05)	0.40	0.08	7.49	0.72
CV(%)	14.41	14.40	15.80	16.67

BD- bulb diameter, ND- neck diameter, AFBW- average fresh bulb weight, BDM- bulb dry matter. Means with the same letter(s) within a column are not significantly different from each other at a 5% level of probability.

3.3.3. Unmarketable bulb yield (t ha^{-1}) and harvest index (%)

As the analysis of variance revealed that unmarketable bulb yield and harvest index was statistically significantly affected ($p \geq 0.05$) by the blended fertilizer rates. Also, the main effect of planting pattern and variety affected significantly unmarketable bulb yield and harvest index, respectively. However, unmarketable bulb yield and harvest index did not influence by variety and planting pattern, respectively and their interaction with NPSB blended fertilizer rate did not significantly ($p>0.05$) influence the above parameters (Table 7). Hence, the maximum unmarketable bulb yield (0.73t ha^{-1}) and harvest index (65%) was recorded from the control, while the minimum unmarketable bulb yield (0.34 t ha^{-1}) and harvest index (57%) was recorded from plot received 300 kg ha^{-1} NPSB. Thus, the mean unmarketable bulb yield and harvest index of onion treated with NPSB at the rate of 0 kg ha^{-1} exceeded the yield of onion plants treated with 300 and 225,150,75 kg NPSB ha^{-1} by about 55, 45, 34, 15% and 12, 9, 6, 5%, respectively (Table 7). This result may be due to an increasing in NPSB fertilizer levels and an increase in the amount of nitrogen fertilizer which reduces the yield of onion tuber that can be unmarketable for the positive role it plays in increasing the new bulb weight ratio. This finding was similar to the results of Fikre *et al*. (2021) who reported that the maximum amount of unsold onion bulb yields was obtained at zero kg per hectare of NPS fertilizer.

The reduction in harvest index at higher rate of NPSB might be due to the total biomass increased more than the economic yield of the crop in response to the application of NPSB blended fertilizer rate which might not be associated with a decrease in total bulb yield. Gawronska *et al*. (1984) stated a supportive idea as although harvest index is commonly used as a key plant parameter, it may not necessarily correlate with high yield. This is possible where the applications of mineral nutrients enables onion crop to exhibit a high rate of assimilate production and maintain active growth later in the season.

Planting patterns (double and single rows) statistically affected unmarketable bulb yield with higher mean value from single row planted onion as compared to double row planted (Table 7). Onion varieties were significantly affected the mean values of harvest index; higher mean value was obtained from red king as compared to red coach variety (Table 7). This indicated that there are genetically differences in harvest index of onion varieties due to more dry matter accumulation by higher nutrients applied to red coach.

Table 7. Main effect of NPSB fertilizer rates, planting pattern and varieties on yields of onion

Treatment	**TBY**	**MBY**	**UMBY**	**HI**
Fertilizer(kg ha^{-1})				
0	13.27e	12.53e	0.73a	0.65a
75	21.33d	20.73d	0.62a	0.62b
150	30.28c	29.80c	0.48b	0.61b
225	35.47b	35.06b	0.40bc	0.59c
300	41.33a	41.00a	0.34c	0.57d
LSD(0.05)	3.74	3.66	0.13	0.01
Planting pattern				
Double row	28.73a	28.28a	0.45b	0.61a
Single row	27.94a	27.37a	0.57a	0.61a
LSD(0.05)	2.37	2.31	0.08	0.01
Varieties				
Red coach	29.39a	28.92a	0.48a	0.60b
Red king	27.28a	26.73a	0.55a	0.61a
LSD(0.05)	2.37	2.31	0.08	0.01
CV	16.01	15.97	30.21	2.30

MBY- marketable bulb yield, UMBY- unmarketable bulb yield, TBY- total bulb yield, HI-harvest index. Means with the same letter(s) within a column are not significantly different from each other at a 5% level of probability.

3.4. Partial Budget Analysis

The partial budget analysis revealed, the highest net benefit of Birr 1,205,372 with higher cost of Birr 159,628 was recorded from the combination of 300 kg NPSB ha^{-1}, double row and red coach variety with marginal rate of 2765.9% which was followed by net benefit of Birr 1,156,372 and cost of Birr 159,628 from the NPSB rate of 300 kg ha^{-1}, single row and red coach variety with the marginal rate of 2147.7%. However, the highest net benefit of Birr 878,894 with least cost production of about Birr 148,006 was obtained from application of NPSB rate 150 kg ha^{-1}, double row and red coach variety with MRR of (6113%). This means that for every Birr 1.00 invested in 150 kg NPSB ha^{-1}, double row and red coach variety, growers can expect to recover the Birr 1.00 and obtain an additional 61.13Birr (Table 8).

The minimum acceptable marginal rate of return (MRR %) should be between 50% and 100% CIMMYT (1988). Thus, the current study indicated that marginal rate of return is higher than 100% (Table 8). This showed that all the treatment combinations are economically important as per the MRR is greater than 100%. Hence, the most economically attractive combinations for small scale farmers with low cost of production and higher benefits were in response to the application of 150 kg NPSB ha^{-1},double row and red coach variety. However, for resource full producers (investors), application of 300 kg NPSB ha^{-1}, double row and red coach variety was also profitable with higher cost and highest net benefit is recommended as a second option.

Table 8. Average cost benefit analysis as influenced by NPSB fertilizer rate and planting pattern on two onion varieties (Red coach/RC/ and Red king/RK/)

Planting pattern	**Variety**	**Fertilizer(kg ha^{-1})**	**Variable cost ETH. Birr per hectare**					**UMBY t ha^{-1}**	**AMBY t ha^{-1}**	**GFB**	**NB (GFB – TVC ETH.birr)**	**MRR=ΔNB/ΔTVC × 100**	**Rank**
			fertilizer cost	**seed coast**	**labor cost**	**other cost**	**TVC**						
Single	RC	0	-	52,800	39,542	35,278	127,620	13.23	11.91	416,850	289,230	207.0	T
Single	RC	75	10,575	52,800	44,114	35,278	142,767	21.98	19.78	692,300	549,533	1718.5	P
Single	RC	150	14,100	52,800	45,828	35,278	148,006	31.67	28.50	997,500	849,494	5725.5	B
Single	RC	225	17,625	52,800	45,828	35,278	151,531	36.00	32.40	1,134,000	982,469	3772.3	F
Single	RC	300	21,150	52,800	50,400	35,278	159,628	41.88	37.69	1,316,000	1,156,372	2147.7	N
Single	RK	0	-	52,800	39,542	35,278	127,620	12.88	11.59	405,650	278,030	2744.1	L
Single	RK	75	10,575	52,800	44,114	35,278	142,767	20.40	18.36	642,600	499,833	1464.3	R
Single	RK	150	14,100	52,800	45,828	35,278	148,006	28.33	25.50	892,500	744,494	4670.0	D
Single	RK	225	17,625	52,800	45,828	35,278	151,531	33.97	30.57	1,069,950	918,419	4934.0	C
Single	RK	300	21,150	52,800	50,400	35,278	159,628	38.98	35.08	1,227,800	1,068,172	1849.5	O
Double	RC	0	-	52,800	39,542	35,278	127,620	13.62	12.26	429,100	301,480	2395.3	M
Double	RC	75	10,575	52,800	44,114	35,278	142,767	22.27	20.04	701,400	558,633	1697.7	Q
Double	RC	150	14,100	52,800	45,828	35,278	148,006	32.60	29.34	1,026,900	878,894	6113.0	A
Double	RC	225	17,625	52,800	47,257	35,278	152,960	37.27	33.54	1,173,900	1,020,940	2867.3	I
Double	RC	300	21,150	52,800	50,400	35,278	159,628	43.33	39.00	1,365,000	1,205,372	2765.9	k
Double	RK	0	-	52,800	39,542	35,278	127,620	13.33	12.00	420,000	292,380	2852.4	J
Double	RK	75	10,575	52,800	44,114	35,278	142,767	20.68	18.61	651,300	508,533	1427.0	S
Double	RK	150	14,100	52,800	45,828	35,278	148,006	28.50	25.65	897,750	749,744	4604.1	E
Double	RK	225	17,625	52,800	47,257	35,278	152,960	34.57	31.11	1,088,850	935,890	3757.5	G
Double	RK	300	21,150	52,800	50,400	35,278	159,628	41.12	37.01	1,295,350	1,135,722	2996.9	H

IV. CONCLUSION AND RECOMMENDATIONS

Increasing application of NPSB fertilizer rate were markedly increased growth and yields of onion up to the rate of 300 kg NPSB ha^{-1}. Thus, the highest plant height(63.83cm), leaf length(52.8cm), leaf number(14.74), bulb diameter(6.89cm) and neck diameter(1.31cm) was obtained from NPSB fertilizer rate of 300 kg ha^{-1} with double row planting method and red coach variety. The study also depicts that significantly highest days to 90% maturity (109), fresh leaf weight (72.8g), shoot dry matter per plant (8.48g), total dry biomass (19.79g), bulb dry matter (11.31g), marketable bulb yield (41t ha^{-1}), and total bulb yield (41.33t ha^{-1}) were recorded in the treatment combination of double row planting method, hybrid red coach onion variety and 300 kg ha^{-1} NPSB blended fertilizer applied. However, the highest unmarketable bulb yield (0.73t ha^{-1}) and harvest index (0.65) was obtained from 0 kg ha^{-1} NPSB blended fertilizer rate combined with single row planting method and red king variety. The partial budget analysis revealed that the highest net benefit of Birr 1,205,372 with higher cost (159,628 Birr) was recorded from the combination of 300 kg NPSB ha^{-1}, double row and red coach variety with marginal rate of 2765.9%. However, the highest net benefit of Birr 878,894 with least cost production of about Birr 148,006 were obtained from application of NPSB rate 150 kg ha^{-1}, double row and red coach variety with MRR of (6180%) in the study area. Thus, in conclusion, the current finding results revealed that the most economically attractive combinations for small scale farmers with low cost of production Birr 148,006 and higher benefits of Birr 878,894 were in response to the combinations of 150 kg NPSB ha^{-1} fertilizer rate with double row planting method and red coach variety in the study area. However, for resource full producers (investors), application of 300 kg NPSB ha^{-1} with double row (40cm* 20cm*7cm between row, within row and between plants, respectively) and red coach variety was also profitable with higher cost and highest net benefit as onion bulb crop is a heavy feeder of fertilizers. These findings can be utilized for enhanced onion production and productivity in the study area. However, there is a gap that has to be linked through further study: Research in the study area has to look replicating season and areas using hybrid varieties of onion within double row planting method in combination with blended NPSBZn fertilizer for enhancing bulb yield and alleviate soil fertility problems.

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