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Research Article

Growth and Yield of Onion (*Allium cepa* L.) as Affected by Variable Rates of Poultry Manure and Mineral Nitrogen Fertilizer at Alage, Central Rift Valley Ethiopia

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Abstract

Onion is one of the important vegetable crops produced in many home gardens and in some extent commercially in different parts of Ethiopia. Therefore, this experiment was conducted at Alage Central Rift Valley of Ethiopia with the objectives of assessing the growth, yield, and quality response of onion to the variable rates of poultry manure and mineral nitrogen fertilizer. The experiment comprising of three nitrogen levels (0, 46, and 92 kg ha^{-1}) and four levels of poultry manure (0, 5, 10, and 15 t ha^{-1}) were laid out in a randomized complete block design with three replications. The result indicated that leaf length, leaf number, days to maturity, bulb length, and bulb dry matter content were significantly influenced by main factors. Application of poultry manure at the rate of 15 t ha^{-1} recorded the highest total bulb yield (63.33 t ha^{-1}) and marketable bulb yield (62.52 t ha^{-1}), but statistically, there was no significant difference between 15t ha^{-1} and 10t ha^{-1} poultry manure application. The results of the partial budget analysis showed that 15 t ha^{-1} poultry manure application gave the highest marginal rate of returns. Since the highest bulb yield and maximum marginal rate of returns are obtained at 15 t ha^{-1} poultry manure application, this rate can be recommended for onion production in the researched area, and areas having similar agro-ecologies. However, as the research is conducted for a single season and location, repeating the experiment over location and year will be required to give a conclusive recommendation.

Keywords

Bulb Yield, Growth Parameter, Nitrogen Fertilizer, Onion and Poultry Manure

1. Introduction

Onion (*Allium cepa L.*) belongs to the genus *Allium* of the family *Alliaceae* [9]. It is one of the most important vegetable crops commercially grown in the world. It probably originated in Central Asia between Turkmenistan and Afghanistan where some of its relatives still grow as a wild. Onion from Central Asia, the supposed onion ancestor had probably migrated to the Near East [29]. Although the green shoots of salad onion are important, the crop is mostly grown for its bulb. Onions contribute significant nutritional value to the human diet and have medicinal properties and are primarily

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consumed for their unique food flavoring purpose and distinctive pungency attributed by the presence of volatile oil (*Allylpropyl disulphide*) [38]. The mature bulbs also contain some starch, appreciable quantities of sugars, some proteins, and vitamins such as vitamin A, B, and C [14].

Onion is grown in more than 130 countries of the world with annual production of 86.34 million metric tons [24]. Onion ranks second after tomato among vegetable crops in area coverage [23]. The world's top producer of onion is China, contributing about 28% to the total world production followed by India (19%). In terms of productivity, however, Ireland is the first (67.3 t/ha), followed by Republic of Korea (63.8 t/ha), USA (55.3 t/ha) and Spain (53.5 t/ha) [22]. In 2013, an estimated yield of 85,795,190.57 tons of onion bulb produced from 4.4 million hectares of land worldwide [24].

In Africa, the major producers of onion are Egypt, Algeria, Morocco and South Africa with corresponding average national yield of 25, 13.6, 18.2 and 21.1 t ha^{-1}, respectively. Vegetables including onion are produced in many home gardens and to some extent, in commercial terms in different parts of Ethiopia [21]. The major producers are, however, the small-scale farmers using mainly rainfall, although some produced using irrigation [13]. Vegetable production of the smallholder farmers in the country is mainly for self-sufficiency and to improve their income [7].

Improvement in environmental conditions with respect to public health has been observed as adoption of organic farming by farmers in the world [16]. Manure is among the organic sources of fertilizer used as an input in the organic farming system. Manures serve as safer sources of nutrition as they are environmentally friendly, release their nutrients in a slow and steady manner to crops in the field, thereby, activating soil microbial activities [16]. Organic manures sustain cropping systems through better nutrient recycling and improvement in soil physical, chemical and biological properties [48].

In the study area, the use of organic fertilizer including poultry manure is not a common practice. Therefore, vegetable production is solely depends on mineral source of fertilizers which is limiting onion production and contributing to environmental pollution. Besides, the use of mineral source of fertilizer may not also be wise at small scale farmer level due to its high cost, less accessibility and reduced profit margin. However, no sufficient information is available on the combined application of poultry manure and inorganic nitrogen fertilization, which can otherwise solve the aforementioned problems.

The use of poultry manure to meet the nutrient requirement of crops would be an inevitable practice in the years to come for sustainable agriculture since organic manure generally improves the soil's physical, chemical and biological properties along with improving the water holding capacity of the soil and, thus, resulting in enhanced crop productivity. Therefore, optimizing sole and combined use of mineral and organic sources of fertilizers could be the better option to maximize crop productivity, environmental and economic sustainability. This indicates the existence of an urgent need to study the effect of combined application of poultry manure and inorganic fertilizer to optimize onion yield in the era of climate change. The main purpose of the present study was, therefore, to assess the effects of poultry manure and mineral nitrogen fertilizers application on the growth, yield and quality performance of onion.

2. Materials and Methods

2.1. Description of the Study Area

The study was conducted in the experimental field of Alage Agricultural Technical and Vocational Education and Training College. The site is located 217 km away from the capital city, Addis Ababa, in the southern direction and 32 km west of Bulbula town in the vicinity of Abidjata and Shalla lakes. It is situated at 7°65' N latitude and 38°56' E longitudes and at an altitude of 1600 meters above sea level in the dry plateau agro ecology of the southern part of the central rift valley of Ethiopian. The area is characterized by a bimodal rainfall pattern where short rainy season occurs during the months of March and April and the main rain starts in June and extends to September. The area receives relatively high amount of rainfall is in the months of July and August. The mean total annual rainfall is 800mm, with annual mean minimum and maximum temperatures of 11℃ and 29℃, respectively. The soil textural class of the area ranges from sandy loam to sandy clay loam with some clay loam and few clay soils [18]. Its reaction is slightly alkaline (pH = 7.87), which is suitable for onion production [42]. The soil is medium in total nitrogen (0.14%) and organic carbon (1.61%) [56], and low in phosphorus (3.38 mg/kg) and EC (1.24 ds/m) [41].

2.2. Experimental Treatments and Design

The experiment consisted of factorial combinations three levels of mineral nitrogen fertilizer (0, 46, and 92 kg ha^{-1}) and four levels of poultry manure (0. 5, 10 and 15 t ha^{-1}) which were laid out in randomized complete block design (RCBD) with three replicates. Each treatment combination was assigned randomly to the experimental units within a block. The onion plants were planted on the plots using double rows on ridges with spacing of 40cm (Centimeter) between ridges 20cm between the double rows and 10cm between plants (40cm x 20cm x 10cm). Each experimental plot had 2 m length and 2 m width having an area of 4 m^2, with six double rows, and 20 plants per row and, thus, total plants were 200 per plot. The distance between plots and blocks were 0.5 m and 1 m, respectively.

Table 1. *Treatment combination of mineral nitrogen and poultry manure with their respective codes.*

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

2.3. Methods of Data Analysis

All the relevant data collected from the experimental plots were subjected to analysis of variances (ANOVA), which was computed using SAS (Statistical Analysis System) computer software program (Version 9.2). Significant treatment means were compared using least significant difference (LSD) test at P<0.05 probability level.

2.4. Partial Budget Analysis

Partial budget analysis was conducted using the methodology described by [12]. It was used to organize experimental data and information about the cost and benefits of various alternative treatments. Bulb yield ha^{-1}, gross benefit (GB), total variable cost (TVC) and net benefit (NB) are concepts used in the partial budget analysis. The following formula was used to estimate the cost and benefits of different treatment combinations: The (gross field benefit) GFB ha^{-1} was obtained as a product of real price of onion yields for each treatment.

$$\text{Gross benefit} = \text{Adjusted yield} \times \text{unit price}$$

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

3. Result and Discussion

3.1. Selected Soil Physico-Chemical Properties of the Experimental Area

Results of laboratory analysis of the soil before planting showed that it was silty clay in texture, having particle size distribution of 17% sand, 43% clay and 40% silt. Its reaction was slightly alkaline (pH value of 7.11), which is believed to be suitable for onion production [42]. The soil was medium in total nitrogen (0.14%), available phosphorus (22.66 ppm) and organic carbon (1.63%) [56]. The CEC (Cation Exchange Capacity) content of the experimental soil before was 38.72 cmol (+) kg^{-1}, with organic matter content of 2.81% and EC of 1.94 ds/m. After harvesting, the soil analysis was done for the plots which were received the respective treatment combinations, where the soil samples from the three blocks were composited for each treatment. Accordingly, the pH level of the soil gradually increased with increasing rate of N fertilizer and poultry manure (PM) (Table 3). The result showed that total nitrogen content was in the ranges of medium to high (0.12%-0.25%), while electrical conductivity value of the soil ranged from 1.26 to 1.50 ds/m, which was in low range [41]. On the other hand, CEC of the soil after harvesting was high which indicates the high cations holding capacity of clay soils [32, 4]. In general, results of the soil analysis after harvesting showed increasing trend with increased rates of N and PM application for Av. P and OM content, though values similar to those measured before planting were observed in some cases (Table 2).

3.2. Phenology and Growth Parameters

3.2.1. Plant Height

Highly significant difference (P<0.001) in plant height was observed due to main effect of nitrogen fertilizer and poultry manure application as well as their interaction effects (Figure 1). Numerically the maximum plant heights was observed from the application of 15 t ha^{-1} of poultry manure with the mean values of (55 cm) followed by application of poultry manure at the rate of 10 t ha^{-1} (54.66 cm) and 5 t ha^{-1} (52.66cm). However, the lowest (49.33cm) plant height was recorded from 0 t ha^{-1} of poultry manure application. The observed differences could be due to the difference in application rate of poultry manure in which increment in poultry manure especially in nitrogen availability enhances vegetative growth though increasing cell division and elongation. This result was in line with the findings of Farooq et al. [20], who reported an increase in height of plants with increased rate of application of organic fertilizers [20].

Table 2. Effects of poultry manure (PM) and nitrogen (N) fertilizer on some soil properties after harvesting at Alage, Ethiopia, during 2020 growing season.

No.	Treatment combination	Chemical properties of sampled plots soil					
		pH	EC (ds/m)	CEC (cmol(+)/kg	TN%	Avai.P (ppm)	OM%
1.	0 tha^{-1} PM +0 kg N ha^{-1}	7.10	1.26	38.20	0.12	20.31	0.63
2.	5 t ha^{-1} PM+0 kg N ha^{-1}	7.14	1.28	38.41	0.18	25.50	1.43
3.	10 t ha^{-1} PM+0 kg N ha^{-1}	7.17	1.31	38.50	0.22	28.82	1.51
4.	15 t ha^{-1} PM+0 kg N ha^{-1}	7.21	1.35	39.56	0.22	29.46	1.91
5.	0 t ha^{-1} PM+46 kg N ha^{-1}	7.15	1.30	38.30	0.17	22.32	0.65
6.	5 t ha^{-1} PM+46 kg N ha^{-1}	7.18	1.37	38.70	0.25	27.25	1.63
7.	10 t ha^{-1} PM+46 kg N ha^{-1}	7.21	1.40	39.49	0.31	29.50	1.89
8.	15 t ha^{-1} PM+46 kg Nha^{-1}	7.24	1.50	41.41	0.35	33.00	2.21
9.	0 t ha^{-1} PM+92 kg N ha^{-1}	7.14	1.33	38.50	0.19	26.11	0.65
10.	5 t ha^{-1} PM+92 kg N ha^{-1}	7.21	1.39	39.10	0.30	28.75	1.66
11.	10 t ha^{-1} PM+92 kg Nha^{-1}	7.30	1.45	39.50	0.32	30.33	1.94
12.	15 t ha^{-1} PM+92 kg Nha^{-1}	7.35	1.50	41.54	0.35	33.24	2.23

Application of Nitrogen fertilizer at the rate of 92 kg ha^{-1} resulted with the tallest plant height (54.75cm) followed by 46 kg N ha^{-1} while, the lowest plant height was recorded from the control treatment. The increase in height in response to increasing the rate of nitrogen may be ascribed to increased availability of nitrogen in the soil for uptake by plant roots that have enhanced vegetative growth through increasing cell division and elongation [31].

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

This result is in line with the findings of [11] who observed a significantly taller plant treated with both organic and inorganic fertilizers compared with the unfertilized plots. Similarly, [28] have reported that organic manure and inorganic fertilizer supplied all the essential nutrients, resulting in increase of measured variables like plant height. [35] also reported that a significant increase in plant height of onion with increasing levels of Vermi compost (from 10 to 30 t ha^{-1}) and N fertilizer (from 50 to 200 kg ha^{-1}).

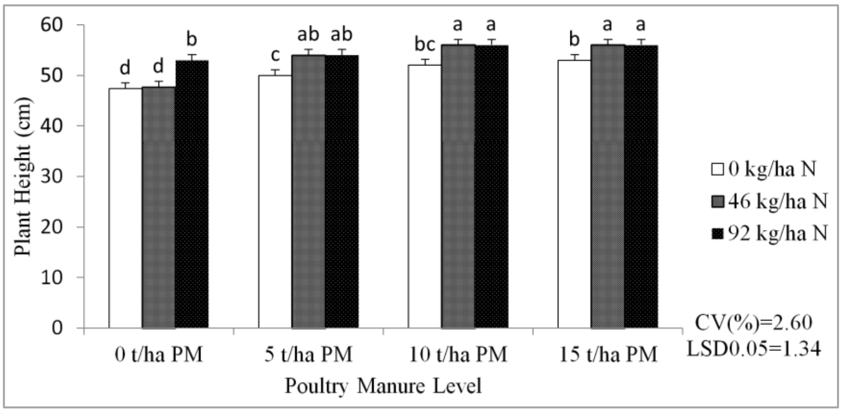

Figure 1. *Interaction effects of poultry manure and nitrogen levels on plant height (cm) of onion grown at Alage, Ethiopia, during 2020 cropping season.*

3.2.2. Number of Leaves Per Plant

Application of poultry manure significantly increased the number of leaves per plant as compared to the control treatment (Table 4). The highest leaf number (12.55) was obtained from application of PM at the rate of 15 t ha^{-1} followed by 10 t ha^{-1} of PM (12.33). However, plants fertilized with 15 and 10 t ha^{-1} did not differ statistically with each other. The lowest leaf number (9.66) was recorded from unfertilized plants. The higher number of leaves per plant and plant height in the amended treatments over the control check could be attributed to increases in vegetative growth, resulting from the significant roles or effects of available essential plant nutrients in the synthesis of the different components of protein required for leaf development, photosynthesis and metabolic processes required for plant growth, thus enhancing rapid growth [51].

In line with this, it has been reported that organic manures and inorganic fertilizers support a lot of vegetative growth as a result of high supply of nutrients, especially nitrogen [53]. [39] Have reported higher number of leaves per plant on plots treated with cow dung. Similarly, [40] have also reported that application FYM has positively influenced leaf number of onion. In agreement with the present study, it has been observed that application of FYM significantly affected the number of leaves of onion [6].

3.2.3. Leaf Length

The study indicated that, statistically there were no significant differences observed among the treatments except with the control. The tallest leaf length was recorded from the application of 15 t ha^{-1} of poultry manure with the mean value of (52.04 cm) followed by 10 t ha^{-1} (51.66) and 5 t ha^{-1} (50.39) poultry manure application. While the shortest (45.70) leaf length was recorded from the unfertilized plants. As the result showed the leaf length was increased with increased poultry manure, this might be due to high nutrients content of the PM including nitrogen (Table 3).

3.2.4. Days to Maturity

Days to maturity was significantly delayed (113 days) by the application of nitrogen fertilizer at the level of 92 kg ha^{-1}, followed by 46 kg ha^{-1} N level; while plants from unfertilized plots matured earliest (109 days). The result indicates that the prolonged time required by the plants to reach maturity at higher rates of nitrogen fertilizers may be due to enhanced cell division and stimulation of vegetative growth which, as a result, delayed maturity of the plants.

The current observation is in line with [10, 37, 54] who reported that higher nitrogen levels resulted in excessive vegetative growth and delayed maturity. This result also supported by [48] who reported that the application of higher nitrogen levels to potato promoted excessive vegetative growth and delayed maturity (table 3). The result clearly indicated that days of maturity were prolonged in response to increased levels of poultry manure and mineral nitrogen fertilizer. This may be attributed to nitrogen contained in both fertilizers which prolonged the vegetative growth of onion.

Table 3. *Main effects of poultry manure and nitrogen fertilizer rates on leaf length, leaf number and days to maturity of onion grown at alage, Ethiopia, during 2020 cropping season.*

Treatments	Leaf length (cm)	Leaf number	Days to maturity (day)
PM (t ha^{-1})			
0	45.70^{b}	9.66^{c}	108.77^{c}

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

3.3. Yield and Yield Component Parameters

3.3.1. Bulb Length

Result from the analysis of variance revealed that the main effects of PM and mineral N fertilizer rates influenced the bulb lengths of onion. However, the two factors did not interact to influence bulb length. The application of 15 t ha^{-1} PM were produced the largest (4.28cm) bulb lengths followed by 10 t ha^{-1} PM application (4.01cm) but, there were no significant difference observed between them. While the lowest bulb length was recorded from the plant received zero PM, which mean from unfertilized plants. In this result with increasing application rates of poultry manure the bulb length also increased.

In agreement with the present study, the use of organic fertilizer increased the length of onion bulbs as observed by [3, 34]. In contrast with the present study, [25, 40] found that no difference in onion bulb lengths due to application of organic and mineral fertilizers. [10] Report that this could be due to the fact that nitrogen is responsible for vegetative growth of plants rather than bulb length.

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

The result agreed with observation of [8] who reported that the highest bulb length was obtained from 150 kg N ha^{-1}. Similarly, [46] reported that bulb length significantly increased with the increases of nitrogen fertilizer up to 150 kg ha^{-1}. The longest bulb length with the increased application rates of nitrogen dose may be due to higher synthesis of carbohydrates in the leaf and their translocation to the bulb, which comparatively helped in the increased length of onion bulbs [59, 34].

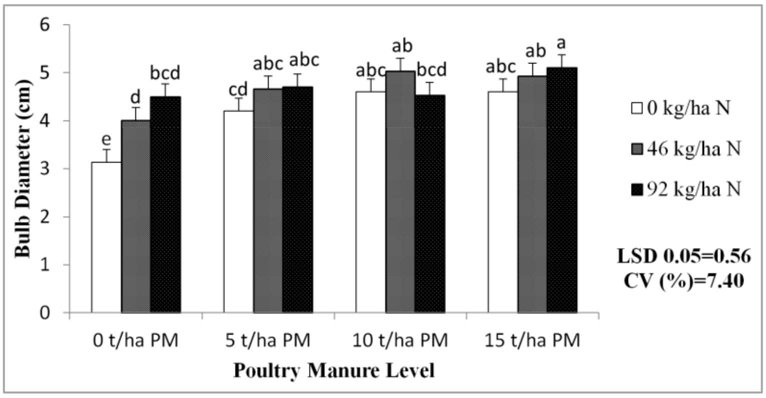

Figure 2. Interaction effects of poultry manure and nitrogen levels on the bulb diameter (cm) of onion grown at Alage, Ethiopia, during 2020 growing season.

3.3.2. Bulb Diameter

The effect of nitrogen significantly influenced the bulb diameter. The highest bulb diameter (4.70cm) was recorded from the plant treated with 92 kg ha^{-1} nitrogen followed by 46 kg ha^{-1} nitrogen (4.65cm) while the shortest (4.13 cm) bulb diameter was obtained from unfertilized plants. The analysis revealed that there was no statistical different between 92 and 46 kg ha^{-1} nitrogen application. The present result was supported by the finding of [58] who found that application of NPS fertilizer had a profound effect on bulb diameters of Adama red variety of onion. The current result showed that the bulb diameter was higher with application of higher doses of N, which may be attributed to highest synthesis of carbohydrate in the leaf and their translocation into bulb as reported by [31]. Similarly, [30] showed that increasing the nitrogen level significantly increased bulb diameter of onion. This might also be ascribed to the role of N in promoting efficient utilization of other nutrients [45]. The result also in agreement with that of [27, 59, 36, 46, 47] who reported a significant increase in the diameter of onion bulbs due to the application of N ranging between 100 - 200 kg ha^{-1}.

Ojeniyi, S. O. [49] Reported increased onion bulb diameter and vitamin C content with combined application of organic manure and NPK fertilizer. Similarly [35] have also reported increased bulb diameter weight on combined application of organic and bio fertilizers and linked it to accelerated synthesis of chlorophyll and amino acids, resulting in more translocation of photosynthesis from leaves to the bulbs translating to increased bulb and diameter of onions.

3.3.3. Average Bulb Weight

The main effect of poultry manure and its interaction with nitrogen fertilizer did not significantly influence average bulb weight of onion. However, the mineral nitrogen fertilizer in its main effects were significantly influenced ($P<0.01$) the average bulb weights of onion. The correlation analysis reviled that average weight of bulb was found to be positively and significantly correlated with bulb length ($r=0.54$), leaf number ($r=0.43$), plant height ($r=0.53$) and total biomass yield ($r=0.42$) indicating that N fertilization and poultry manure increased bulb weight by improving these parameters. [1] Indicated that bulb weight had positively strongly association with plant height, leaf number and leaf length as affected by nitrogen and phosphorus fertilization.

3.3.4. Total Biomass Yield

Regarding nitrogen application the highest total biomass yield were obtained from the plants treated with 92 kg ha^{-1} N (75.66 t ha^{-1}) followed by 46 kg ha^{-1} N with the mean value of (69.91 t ha^{-1}) while the lowest were recorded from unfertilized plants (67.08 t ha^{-1}). The result was consistent with the finding of [17] who reported the highest total biomass yield of onion at the application of higher rates of nitrogen. The total biomass yields were decreased with decreasing nitrogen application. The increase in biomass yield in response to the increased N application may be ascribed to the predominant role that N plays in enhancing the physiological function of plants through promoting leaf expansion and photosynthesis [5].

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

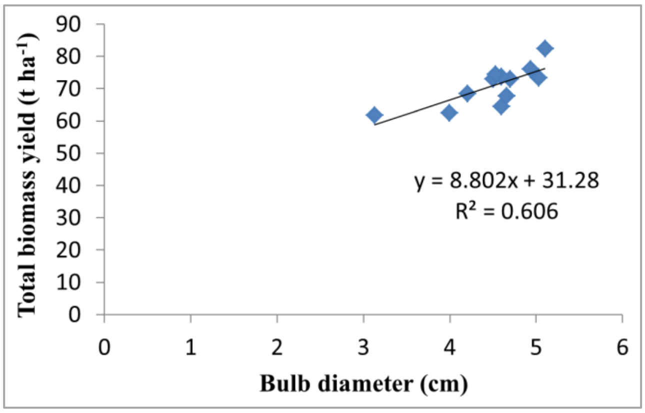

Figure 3. *Relationship between total biomass yield and bulb diameter.*

3.3.5. Total Bulb Yield

The analysis of variance showed that the main effect of PM was significantly ($P<0.05$) influenced the total bulb yield of onion, but mineral N fertilizers and interaction effects were not significantly influenced the total bulb yield of onion. Generally, increasing application rate of PM produced highest total bulb yield. The highest total bulb yield (63.33 t ha^{-1}) were obtained by the application of 15 t ha^{-1} PM, while, the lowest (53.44 t ha^{-1}) total bulb yield were recorded from unfertilized onion plants (Table 4). The results were agreed with the finding of [43] who reported that the Plant height, total dry matter, single bulb weight, yield and nutrients uptake at different growth stages of onion varied significantly due to application of poultry manure and inorganic N fertilizer.

The present study were also in line with the finding of [40] who reported that the highest rate of total bulb yield increase with the application of FYM and mineral fertilizers. Another author reported that the application of 20 t ha^{-1} FYM increased the total bulb yield of onion by 24% compared to controls [25]. The result in the present study are generally agreed with the findings of [52] who found animal manure applications increased onion yield. Similarly, [26] reported an increase of 32.9% onion bulb yield compared to the control treatment. [19] Reported the application of poultry litter at the rate of 15 t ha^{-1} produced the highest yield per hectare.

The finding of [15] reported that yield and yield attributes of garlic bulbs increased with the increases in the rates of nitrogen, phosphorus, and sulfur, which was also in line with to the present result of nitrogen application.

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

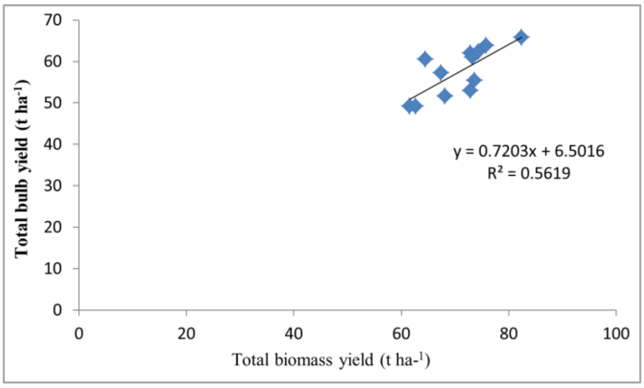

***Figure 4.** Relationship between total biomass yield and total bulb yield of onion.*

***Table 4.** Main effects of poultry manure and mineral nitrogen levels on total bulb yield dry matter content and harvest index of onion grown at Alage, Ethiopia, during 2020.*

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

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

3.3.6. Bulb Dry Matter Content

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

According to the present result, the highest (11.85%) bulb dry matter content was recorded at the control plants and the lowest was recorded (8.7%) at 15 t ha^{-1} poultry manure application. It means that the more application of poultry manure the lower the bulb dry matter content (Table 4). The study was disagreed with the findings of [33] who reported that the highest amount of dry matter content was recorded from the application of 57.5 kg ha^{-1} N with 10 t ha^{-1} poultry manure at all growth stages, the plants in the control treatment produced the lowest dry matter at all growth stages.

Regarding mineral nitrogen fertilizer application the highest (11.87%) bulb dry matter content was recorded from the plants treated with 0 kg N ha^{-1} followed (10.62%) by 46 kg ha^{-1} N while the lowest bulb dry matter (9.04%) was recorded from the nitrogen application at the rate of 92 kg N ha^{-1}. Similarly, bulb dry matter content decreased with increasing application rates of mineral nitrogen fertilizer (Table 6). In line with dry matter accumulation response to N application in this result, [43] reported that dry matter of onion bulbs was not affected by nitrogen application. This result indicates that nitrogen fertilizer at lower rate would result in bulb with proportional dry matter content of onion. [50] Also reported that nitrogen application had no effect on potato tuber dry matter. According to [10, 54] excessive nitrogen resulted in a vigorous vegetative growth and reduced dry matter contents of onion bulbs.

3.3.7. Harvest Index

Analysis of variance indicated that harvesting index was significantly influenced by the main effects of poultry manure and nitrogen fertilizer application as well as by their interaction effects. The analysis of variance revealed that the main effects of poultry manure application had significant ($p<0.001$) influence on harvest index. With poultry manure application the highest (81.55%) harvest index were recorded at the rate of 15 t ha^{-1} PM followed by 10 t ha^{-1} PM (80.44%) and at 5 t ha^{-1} (73.55%) while the lowest were recorded at 0 t ha^{-1} PM (71.77%) application.

The highest harvest index (80.00%) were obtained from 92 kg N ha^{-1}, while the lowest harvest index (72.16%) was recorded from 0 kg ha^{-1} N application. This result was supported by the finding of [2] who observed that harvest index of onion increased with increasing nitrogen rate up to 115 kg ha^{-1} compared to the control. This could be attributed to improved photosynthetic capacity of plants and movement of assimilates from the leaves to the bulbs during the growing period.

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

The result were in line with the finding of [57, 44] who reported that the highest harvest index for Adama Red cultivar of onion was recorded from treatments that received N and FYM at 25 kg N ha^{-1}+ 8 t FYM ha^{-1}. This finding is also supported by the results of [55] who reported the application of 50 kg N ha^{-1} combined with 10 t ha^{-1} manure showed maximum harvest index of garlic.

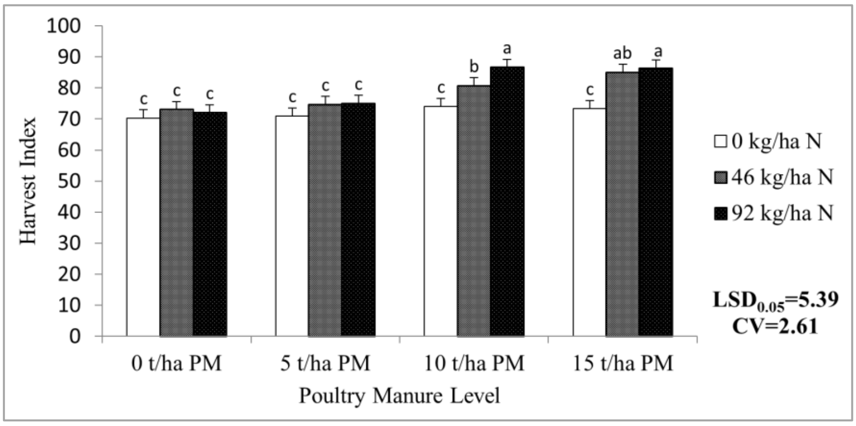

Figure 5. *Interaction effects of poultry manure and nitrogen levels on harvest index of onion grown at Alage, Ethiopia, during 2020.*

3.4. Partial Budget Analysis

The economic analysis was done for only poultry manure application, where significant variation was observed. Partial budgeting is a method of organizing experimental data and information about the costs and benefits of various alternative treatments. According to [12] the average yield was adjusted downward by 10% in order to represent the yield obtained by the farmers as compared to that of the research. In line with this, the analysis revealed that the highest gross field benefit (450,080 ETB ha^{-1}) and net benefit (430,580 ETB ha^{-1}) were obtained from 15 t ha^{-1} PM application, whereas the lowest gross field benefit (377,280 ETB ha^{-1}) was recorded for the control plot and the lowest net benefit (375,980 ETB ha^{-1}) was obtained from 5 t ha^{-1} PM. The dominance analysis indicated that application of only 5 t ha^{-1} PM was dominated and thus, further marginal rate of return analysis was not considered for the treatment.

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

Table 5. *Partial Budget Analysis for poultry manure application at Alage.*

Treatment	**0 t ha^{-1}**	**5 t ha^{-1}**	**10 t ha^{-1}**	**15 t ha^{-1}**
Average yield (t ha^{-1})	52.40	53.13	58.63	62.52

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

Where, ETB= Ethiopian Birr (currency); price for poultry manure= 1.00 ETB kg^{-1}.

Table 6. Analysis of Marginal rate of return for poultry manure application at Alage.

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

4. Conclusion & Police Implication

The main effects of poultry manure and nitrogen fertilizer levels significantly affected most plant growth and bulb yield characters of onion. Plant height, leave number per plant, leaf length, days to maturity, bulb length, bulb diameter and harvest index were increased as the poultry manure and nitrogen fertilizer increased while the unmarketable bulb yield and bulb dry matter content were significantly reduced with increased poultry manure and nitrogen fertilizer levels.

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

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

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

Correlation analysis indicated that marketable bulb yield positively correlated with most of growth parameters. The partial budget analysis revealed that highest gross field benefit (450,080 ETB ha^{-1}) and net benefit (430,580 ETB ha^{-1}) was obtained from 15 t ha^{-1} PM (Poultry manure) application, whereas the lowest gross field benefit (377,280 ETB ha^{-1}) was recorded from the control plot and the lowest net benefit (375,980 ETB ha^{-1}) was obtained from 5 t ha^{-1} PM. The dominance analysis indicated that only 5 t ha^{-1} PM application rate was dominated and further marginal rate of return analysis was not considered for the treatment. The analysis of marginal rate returns (MRR) for this experiment revealed that treatment that received 10 t ha^{-1} and 15 t ha^{-1} PM application had given a marginal rate of return above the minimum acceptable rate (100%).

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

Abbreviations

ANOVA	Analysis of Variance
CEC	Cation Exchange Capacity
Cm	Centimeter
CSA	Central Statistical Agency
EARO	Ethiopia Agricultural Research Organization
FAO	Food and Agricultural Organization of the United Nation
FAOSTAT	Food and Agriculture Organization Statistics
ICAR	Indian Council of Agricultural Research
LSD	Least Significant Difference
PM	Poultry Manure
RCBD	Randomized Complete Block Design
SAS	Statistical Analysis System

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Conflicts of Interest

The authors declare no conflicts of interest.

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