



Response of Onion (*Allium cepa* L.) Bulb to the Combined Effect of Vermicompost and Mineral Fertilizer under Irrigated Soil Condition in Raya Azobo and Kilte-Awulaelo Districts South and Eastern Tigray, Ethiopia

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ABSTRACT

Background: In Ethiopia, onion (*Allium Cepa* L.) is a major vegetable crop. However, due to erratic cultivation, rising mineral fertilizer prices and inadequate soil fertility management, its productivity is declining. Integrated nutrient management is a cost-effective approach to fertilizing soil. If used properly, the combination of vermicomposting with mineral fertilizers is one of the most promising options. Nonetheless, in the study areas, the appropriate application rate of vermicompost and NPSZn fertilizer on onion production has not been well examined.

Methods: A field experiment was conducted in the irrigated soil conditions of Kilte-Awulaelo and Raya Azobo districts. The study used a randomized complete block design with three replications and twelve experimental treatments (4.5, 3 and 1.5 t ha⁻¹ vermicompost rates combined with NPSZn 75, 50 and 25 kg ha⁻¹). Full recommended 6 t ha⁻¹ vermicompost, 100 kg ha⁻¹ NPSZn fertilizer and absolute control were used. The collected agronomic data were subjected to ANOVA using SAS statistical software (SAS 9.0) and mean separation was done using LSD.

Result: Most of the measured onion growth and yield parameters were significantly affected by the joint application of vermicompost and NPSZn. It varies among districts. Maximum bulb yields of 51.2 t ha⁻¹ in Kilte-Awulaelo and 42.5 t ha⁻¹ in Raya Azobo district were obtained from the application of 4.5 t ha⁻¹ vermicompost with 50 kg ha⁻¹ NPSZn and 4.5 t ha⁻¹ vermicompost with 75 kg ha⁻¹ NPSZn respectively. The combined application of vermicompost with NPSZn fertilizer enhanced onion growth and yield.

Key words: Blended fertilizer, Bulb Production, Soil fertility, Worms.

INTRODUCTION

Onion (*Allium cepa* L.) belongs to the genus *Allium* and the family Alliaceae (Krontal *et al.*, 2000). About 374,703.9 tons of onion bulbs were produced in Ethiopia from the 48,443.36 hectares of land that were used for the crop. The Tigray region produces 5.39 t ha⁻¹ compared to the national average of 8.97 t ha⁻¹ (CSA, 2016).

Sustainable onion bulb production in Tigray is severely hampered by the continuous loss of soil fertility and nutrient deficiencies. Therefore, to address the existing soil fertility challenges, resistant crop varieties should be developed, organic and mineral fertilizers should be used and other soil fertility management techniques should be applied (Giday *et al.*, 2015).

The biggest obstacle to crop production for small holder subsistence farmers is soil fertility. The Tigray region has the worst soil fertility decline due to significant nitrogen losses from soil erosion and very low supplemental fertilizer input utilization (Corbeels *et al.*, 2000). To understand the complete system, physical, chemical and biological aspects of healthy soil are employed. Integrated soil fertility management is a preferable solution to the current soil nutrient problem and to increase onion production (Muluaalem and Yebo, 2015).

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Vermicomposting is a new and effective technique for transforming undesirable and almost limitless sources of organic waste into useable substrates. In this process, the digestive systems of specific earthworm species (*Eisenia fetida*) are used to stabilize organic wastes. Earthworm compost is a source of substantial amounts of nutrients, a sizable population of advantageous microorganisms and physiologically active metabolites that may be coupled with nutrients to improve crop quality and yield (Chandan *et al.*, 2015).

Vermicompost is organic manure that slowly releases nutrients to suit the long-term nutritional demands of plants. Cultivation of vegetable crops using vermicomposting is organic, inexpensive, eco-friendly and most importantly it contains a lot of nutrients which results in better yields and growth parameters (Kalika-Singh *et al.*, 2022). Soil fertility and crop yield both depend on integrated nutrient management (Singh and Hussain, 2015). Onion is the most significant and widely consumed vegetable crop grown in the two research sites Kilte-Awulaelo and Raya Azobo districts. The objective of the study was to determine the combined impact of vermicompost and NPSZn fertilizer on onion bulb yield and yield components.

MATERIALS AND METHODS

Description of the study area

The experiment was carried out in two locations at Kilte-Awulaelo and Raya Azobo (Raya Valley) district, under

irrigated soils during the 2022 and 2023 cropping season in Tigray, Ethiopia. Kilte Awulaelo is agro-ecologically classified as midland (Woyna-Dega) having an altitude of 1911 m.a.s.l (Fig 1). The mean annual rainfall was a range from 400 mm to 600 mm ranges from 2010-2014, While, the mean annual temperature in the same year ranges from 160C to 270C (BARD, 2010).

The second experiment was carried out in the southern part of Tigray Raya Azobo district in the Mehoni agricultural research center test station in the same season (Fig 2). The altitude of the district is 1578 m.a.s.l. The mean annual rainfall of 539 mm. The average minimum and maximum temperatures of 12.81 and 23.24°C, respectively.

Description of experimental materials

Bombay red is high high-yielding onion variety and well adapted in both study districts. Bombay red takes 110-120 days for bulb harvest and the variety needs 90-110 days to reach maturity. The recommended spacing of 40 cm

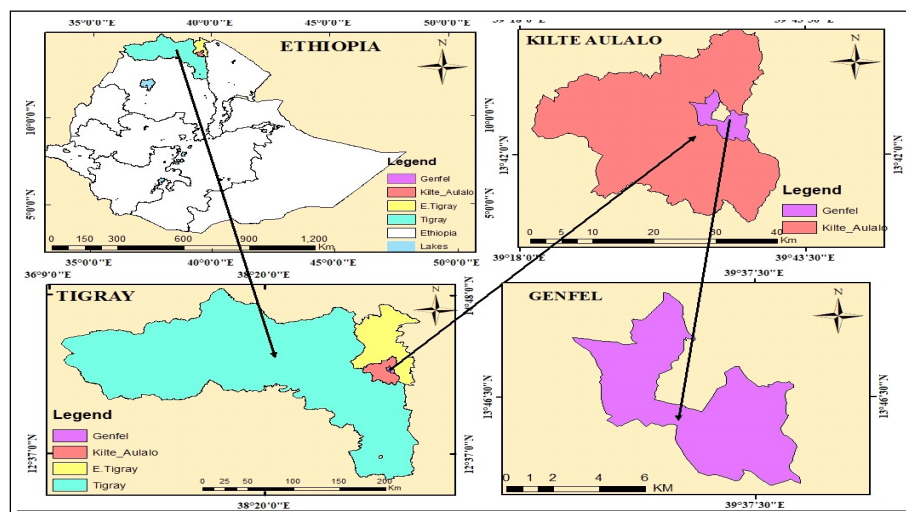


Fig 1: Study area map of Kilte-Awulaelo district.

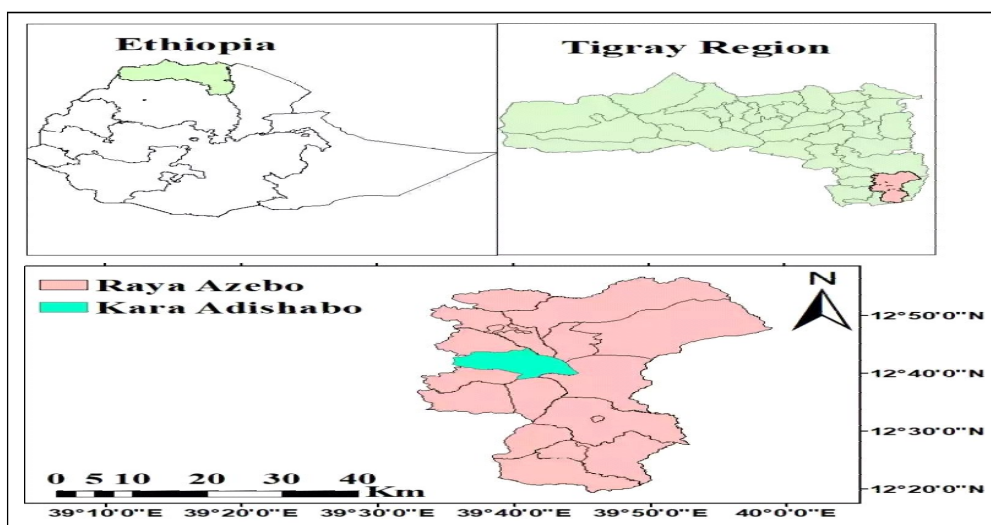


Fig 2: Study area map of Raya Azebo district.

between blocks, 20 cm between rows and 6 cm between plant spacing was used in the study (Hasan, 2021).

Ammonium Sulfo-Phosphate-Zincate (NPSZn) which constituted 18 N- 35.9 P₂O₅-7.7 S- 2.2 Zn⁺⁺ and urea was used as a source of N fertilizer. The recommended application rate for onion crop in the study areas is 100 kg ha⁻¹ of blended fertilizer and 100 kg of urea ha⁻¹ (ATA, 2015; Tegbaru, 2015). The Vermicompost was taken from Amhara Agricultural Research Institute and prepared from organic materials such as crop residues, green plants, cow dung and ashes. The recommended requirement of Vermicompost maximum onion bulb production was (6 ton ha⁻¹) (Singh and Hussain, 2015; Compost *et al.*, 2009).

Experimental treatments and design

A field experiment was laid out in randomized complete block design with twelve treatments in three replications, which accounted for 36 total experimental plots (Table 1). The unit plot size was 2.4m × 2.4m with spacing between blocks (1.5 m) and plots (1m) was used.

Experimental procedures

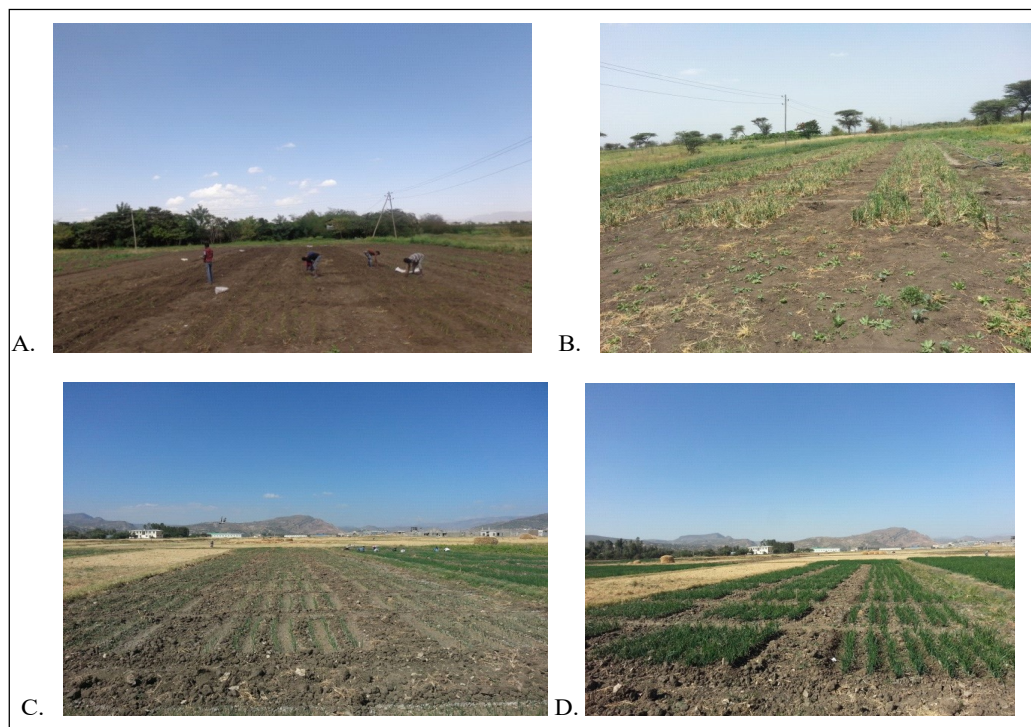
The land was plowed three times by oxen next to a tractor within two weeks difference. Healthy, vigorous and stocky seedlings were selected for field transplanting when the seedlings reached the 2-3 leaf stage and 8-12 cm tall after 55 days after sowing. Healthy seedlings were transplanted to a depth of 3-4 cm by sticking them into the furrows by

hand. Well-decomposed Vermicompost was applied to plots and mixed thoroughly 14 days before transplanting by cutting open furrows and incorporating them into planting rows at a depth of 10-15 cm. The experiment was conducted under irrigation using the furrow irrigation method. Irrigation was applied at intervals of three times a week for the 1st two weeks after transplanting. Afterward, the application of water was extended to five to six days intervals until 14 days left to harvest. In addition, all agronomic practices required for onion production were implemented properly (Appendix Fig 1).

Table 1: Experimental treatment details.

Treatment Description	
4.5 t ha ⁻¹ (VC)	25 kg ha ⁻¹ NPSZn
	50 kg ha ⁻¹ NPSZn
	75 kg ha ⁻¹ NPSZn
3 t ha ⁻¹ (VC)	25 kg ha ⁻¹ NPSZn
	50 kg ha ⁻¹ NPSZn
	75 kg ha ⁻¹ NPSZn
1.5 t ha ⁻¹ (VC)	25 kg ha ⁻¹ NPSZn
	50 kg ha ⁻¹ NPSZn
	75 kg ha ⁻¹ NPSZn
Absolute Control	0
Farmers Practice	100 kg ha ⁻¹ NPSZn
Vermicompost Only	6 t ha ⁻¹ VC

Where, VC: Vermicompost; NPSZn: Nitrogen, Phosphorus, Sulfur, Zinc; kg = kilogram.



Appendix Fig 1: A and B: Kilt-Awulaelo district experimental site. C and D: Raya Azobo district experimental.

Data collection and measurement

Data on growth and yield traits were recorded starting from planting to harvesting. All the agronomic data (days to maturity, leaf number, number of bolting flowers per plot, plant height (cm), mean bulb weight (g), bulb diameter, bulb dry matter content (%), marketable and unmarketable bulb yield (t ha^{-1}) and total bulb yield) were collected from central rows of each plot to avoid border effect. Finally, the crop was harvested and roots and shoots trimmed manually.

Statistical analysis

The collected data were subjected to the analysis of variance (ANOVA) using SAS version 9.0. The least significant difference test (LSD) at a 5% level was made for all significant treatment means using the Pearson correlation coefficients (r) at $\alpha = 0.05$ (Gomez and Gomez, 1984).

RESULTS AND DISCUSSION

Days to bulb maturity

Different rates of combined vermicompost and NPSZn fertilizer application in both districts had a significant ($P < 0.0001$) impact on onion bulb days to maturity (Table 2 and 3) and (Appendix Table 1 and 2). In the districts of Kilte-Awulaelo and Raya Azobo, absolute control showed fewer days to bulb maturity, 111 and 89.33 days, respectively (Appendix Table 1 and 2). However, at the Kilte-Awulaelo and Raya Azobo districts the application of 100 kg ha^{-1} NPSZn followed by the application of 4.5 t ha^{-1} VC + 75 kg ha^{-1} NPSZn resulted in the greatest numbers of days to bulb maturity of 122 and 105.33 days, respectively. The

result showed that days to maturity were extended in response to increased levels of Vermicompost and blended fertilizer.

Nitrogen fertilizer may be responsible for a delay in onion bulb maturity by promoting and enhancing vegetative development at an early stage of plant growth. Moreover Due to the lengthy vegetative development stage, a high nitrogen dose may not be useful in lowering onion bulb days to maturity.

The findings are similar with prior research, which revealed that higher fertilizer rates resulted in prolonged vegetative development of a variety of vegetable crops, including onion and Nitrogen and farmyard manures help to promote vegetative growth before bulb development begins (Gererufael *et al.*, 2020; Alemayehu and Jemberie, 2018; Yebo, 2015; Rathod *et al.*, 2009 and Krantal *et al.*, 2000).

In contrast with our findings Asgele *et al.* (2018) indicated that vermicompost not only improved onion yield, through improving onion nutrient uptake it also speeded maturation.

Plant height (cm)

The experiment revealed that the integrated use of vermicompost and NPSZn in both study districts was extremely significant at $P < 0.0001$ (Table 2 and 3) and (Appendix Table 1 and 2). The application of 4.5 t ha^{-1} VC + 50 kg ha^{-1} NPSZn resulted in the highest plant height (60.3 cm), which is statistically 9.3 cm greater than that of 1.5 t ha^{-1} VC + 25 kg ha^{-1} NPSZn treatment. The 1.5 t ha^{-1} VC + 25 kg ha^{-1} NPSZn and absolute control plants had the shortest plant heights, measuring 51.07 cm and 52.4 cm, respectively. In Raya Azobo district, the maximum plant height of onion (62.93 cm) was obtained from the

Table 2: Effects of Vermicompost and NPSZn fertilizer on the number of leaves per plant and stock number in onion, bulb size diameter and dry matter content at Kilte Awulaelo District.

Treatment	Combinations	DM	PH (cm)	LN	BFN/plot	BD (mm)	BDMC (%)
T ₁	Absolute Control	111.33 ^g	52.40 ^{ef}	7.17	9.67 ^d	45.07 ^e	27.35
T ₂	NPSZn 100 kg ha^{-1} (FP)	122.67 ^a	60.13 ^a	7.83	13.67 ^a	49.27 ^{de}	26.76
T ₃	6 t ha^{-1} VC	116.33 ^{de}	56.40 ^{abc}	7.33	7.67 ^d	52.47 ^{bcd}	26.78
T ₄	4.5 t ha^{-1} VC + 25 kg ha^{-1} NPSZn	119.33 ^{bc}	57.07 ^{abc}	7.27	9.33 ^{bcd}	51.67 ^{cd}	27.76
T ₅	4.5 t ha^{-1} VC + 50 kg ha^{-1} NPSZn	119.67 ^{bc}	60.33 ^a	7.63	10.33 ^{abcd}	57.53 ^a	27.26
T ₆	4.5 t ha^{-1} VC + 75 kg ha^{-1} NPSZn	121.67 ^{ab}	59.63 ^{ab}	7.5	11.67 ^{abc}	57.23 ^{ab}	25.66
T ₇	3 t ha^{-1} VC + 25 kg ha^{-1} NPSZn	114.33 ^{ef}	56.13 ^{cd}	7.27	7.67 ^d	49.00 ^{de}	26.21
T ₈	3 t ha^{-1} VC + 50 kg ha^{-1} NPSZn	118.00 ^{cd}	57.93 ^{abc}	7.2	12.33 ^{ab}	55.07 ^{abc}	27.07
T ₉	3 t ha^{-1} VC + 75 kg ha^{-1} NPSZn	121.33 ^{ab}	60.33 ^a	7.47	12.33 ^{ab}	57.33 ^{ab}	27.64
T ₁₀	1.5 t ha^{-1} VC + 25 kg ha^{-1} NPSZn	113.00 ^{fg}	51.07 ^f	7.18	8.33 ^{cd}	46.33 ^e	26.45
T ₁₁	1.5 t ha^{-1} VC + 50 kg ha^{-1} NPSZn	119.67 ^{bc}	55.20 ^{cde}	7.43	8.00 ^d	48.53 ^{de}	28.31
T ₁₂	1.5 t ha^{-1} VC + 75 kg ha^{-1} NPSZn	118.33 ^{cd}	53.20 ^{def}	6.97	10.00 ^{abcd}	52.67 ^{abcd}	26.10
LSD ($P < 0.05$)		2.85***	3.45***	0.99 ^{ns}	3.84**	4.87***	2.73 ^{ns}
CV		1.43	3.66	8.01	23.38	5.57	6.00

Note: FP: Farmers practice, DM: Days to maturity, PH: Plant height, LN: Leaf number, BFN: Bolting flower number, BD: Bulb diameter, BDMC: Bulb dry matter content. The same letters within a column are not significantly different indicated by, **and ^{ns} highly significant ($P < 0.01$) and non-significant, respectively.

application of 4.5 t ha⁻¹ VC+75 kg ha⁻¹ NPSZn. However, the shortest plant height 49.93 cm was recorded from absolute control followed by the application of 1.5 t ha⁻¹ VC+25 kg ha⁻¹ NPSZn which was 51.07 cm.

The increase in plant height could be attributed to additional essential micronutrients found in Vermicompost,

which promotes plant growth and production on a long-term basis. Nitrogen is an important building block of amino acids and a critical element required for plant growth and development.

Similar to this, Deb *et al.* (2015) revealed that the application of 2.5 t ha⁻¹ Vermicompost and NPK+S+Zn

Table 3: Effects of vermicompost and NPSZn fertilizer on the number of leaves per plant and stock number in onion, bulb size diameter and dry matter content at Raya Azobo District.

Treatment	combinations	DM	PH (cm)	LN	BFN/plot	BD (mm)	BDMC (%)
T ₁	Absolute Control	89.33 ^e	49.93 ^g	6.10 ^e	3.33	43.47 ^d	19.73
T ₂	NPSZn 100 kg ha ⁻¹ (FP)	105.33 ^a	61.13 ^{ab}	8.13 ^{bc}	3.33	52.67 ^{abc}	19.79
T ₃	6 t ha ⁻¹ VC	97.67 ^{bcd}	56.40 ^{cde}	8.00 ^{bc}	2.67	52.73 ^{abc}	22.34
T ₄	4.5 t ha ⁻¹ VC + 25 kg ha ⁻¹ NPSZn	95.33 ^{cde}	57.07 ^{bcd}	7.93 ^{bcd}	2.67	52.60 ^{abc}	22.13
T ₅	4.5 t ha ⁻¹ VC + 50 kg ha ⁻¹ NPSZn	100.33 ^{abc}	60.33 ^{abc}	8.67 ^b	2.67	54.97 ^{ab}	21.29
T ₆	4.5 t ha ⁻¹ VC + 75 kg ha ⁻¹ NPSZn	105.00 ^a	62.93 ^a	10.00 ^a	2.67	56.40 ^a	20.56
T ₇	3 t ha ⁻¹ VC + 25 kg ha ⁻¹ NPSZn	100.33 ^{abc}	56.13 ^{cde}	7.33 ^{cd}	3.00	52.53 ^{abc}	21.96
T ₈	3 t ha ⁻¹ VC + 50 kg ha ⁻¹ NPSZn	100.00 ^{abc}	57.93 ^{bcd}	8.07 ^{bc}	2.67	51.00 ^{abc}	20.02
T ₉	3 t ha ⁻¹ VC + 75 kg ha ⁻¹ NPSZn	102.67 ^{ab}	59.37 ^{abcd}	8.53 ^b	2.67	54.60 ^{ab}	21.52
T ₁₀	1.5 t ha ⁻¹ VC + 25 kg ha ⁻¹ NPSZn	91.00 ^{de}	51.07 ^{fg}	6.83 ^{ed}	3.33	46.67 ^{cd}	20.09
T ₁₁	1.5 t ha ⁻¹ VC + 50 kg ha ⁻¹ NPSZn	100.33 ^{abc}	55.20 ^{def}	7.73 ^{bcd}	3.33	50.20 ^{abcd}	20.76
T ₁₂	1.5 t ha ⁻¹ VC + 75 kg ha ⁻¹ NPSZn	102.67 ^{ab}	53.20 ^{efg}	7.80 ^{bcd}	3.33	49.53 ^{bcd}	19.73
LSD (P < 0.05)		7.01 ^{***}	4.35 ^{**}	1.13 ^{***}	1.15 ^{ns}	6.82 [*]	3.44 ^{ns}
CV		4.2	4.55	8.47	23.120	7.870	9.81

Note: FP = Farmers practice, DM = Days to maturity, PH = Plant height, LN = Leaf number, BFN = Bolting flower number, BD = Bulb diameter and BDMC = Bulb dry matter content. The same letters within a column are not significantly different indicated by, ** and ns- highly significant (P<0.01) and non-significant, respectively.

Appendix Table 1: Mean squares of analysis of variance for degree of freedom, days to maturity, plant height, leaf number, stock number, equatorial diameter, polar diameter and mean bulb weight at Kilde-Awulaelo Districts.

Source of variation	DF	Mean square values						
		DM	PH	LN	SN	ED	PD	MBW
Trt	11	38.03 ^{***}	30.98 ^{***}	0.19 ^{ns}	16.74 ^{**}	56.01 ^{***}	16.70 ^{ns}	346.72 ^{***}
Error	24	2.86	4.30	0.35	5.20	8.35	18.37	47.92
Total	35	-	-	-	-	-	-	-
CV		1.44	3.66	8.01	23.38	5.57	9.29	6.31

Where, ns = Non-significant, * and ** indicates significant difference at probability levels of 5% and 1%, respectively. Trt = Treatment, DF = Degree of freedom, DM = Days to maturity, PH = Plant height, LN = Leaf number, SN = Stalk number, ED = Equatorial diameter, PD = Polar diameter, MBW = Mean bulb weight.

Appendix Table 2: Mean squares of analysis of variance for degree of freedom, days to maturity, plant height, leaf number, stock number, equatorial diameter, polar diameter and mean bulb weight at Raya Azobo Districts.

Source of variation	DF	Mean square values						
		DM	PH	LN	SN	ED	PD	MBW
Trt	11	76.82 ^{**}	47.16 ^{***}	2.79 ^{***}	0.33 ^{ns}	39.40 [*]	1.00 ^{ns}	484.39 [*]
Error	24	17.33 ^{**}	6.67 ^{***}	0.45	0.47 ^{ns}	16.37 [*]	4.45 ^{ns}	191.15 [*]
Total	35	-	-	-	-	-	-	-
CV		4.20	4.55	8.47	23.12	7.86	5.03	16.55

Where, ns = non-significant, * and ** indicates significant difference at probability levels of 5% and 1%, respectively. Trt = Treatment, DF = Degree of freedom, DM = Days to maturity, PH = Plant height, LN = Leaf number, SN = Stalk number, ED = Equatorial diameter, PD = Polar diameter, MBW = Mean bulb weight.

(100:50:100:20:10 kg ha⁻¹) led to the greatest increases in plant height (59.08 cm). Yadav *et al.* (2015) also found that the maximum plant height (74.32 cm) recorded from the application of the recommended dose fertilizer (50%) + Vermicompost (50%) agreed with the present study. A maximum plant height of 53.16 cm was measured after applying 2.5 t ha⁻¹ of the 50 percent recommended dosage of NPK + vermicompost (Suthar and Singh, 2008). Moreover, study by Bagali *et al.* (2012) and Zakari *et al.* (2014) suggested that integrated nutrient supply improve physical properties of soil and increased activity of microbes with higher levels of organic matters might have helped in increasing vegetative growth.

Leaf number

The analysis of variance revealed that the effect of Vermicompost and blended fertilizer ($P < 0.05$) had no significant variation on onion leaf number in Kilte-Awulaelo district (Table 2 and Appendix Table 1). However, it showed that the onion leaf number was significantly ($P < 0.001$) influenced by the combined application of Vermicompost and blended fertilizer at the Raya Azobo experimental site (Table 3 and Appendix Table 2). The combined treatment of VC 4.5 t ha⁻¹ + NPSZn 75 kg ha⁻¹ resulted in the highest number of onion leaves (10 leaves), followed by the application of VC 4.5 t ha⁻¹ + NPSZn 50 kg ha⁻¹, which produced 8.67 leaves.

The increase in onion leaf number in response to increased application of vermicompost and NPSZn fertilizer could be attributed to the role of nitrogen and phosphorus in root and shoot growth, as well as the formation of phosphoproteins and phospholipids that promote plant meristematic activity, resulting in a higher number of leaves per plant.

Similar results were made by Bashir and Madhavaiah (2015), who determined that vermicompost, had a substantial impact on the quantity of leaves. The number of leaves per plant was increased by about 4% in response to increasing Vermicompost from 0 to 5 t ha⁻¹ in the garlic crop. Jeyakumar *et al.* (2007) also reported similar findings that revealed application of farm yard manure and inorganic fertilizer enhance the production of leaves.

Number of bolting flowers

Onion flower bolting was significantly ($P < 0.05$) affected by the combined effect of vermicompost and NPSZn fertilizer in Kilte-Awulaelo district (Tables 2 and Appendix Table 1). The highest bolting flower per plot (13.67) was noted from the application of only NPSZn fertilizer at the rate of 100 kg ha⁻¹. The minimum bolting flowers were recorded (7.67) from treatment which received 6 t ha⁻¹ vermicompost only. In line with this study Al-Fraihat (2009) and Abdissa *et al.* (2011) reported that as nitrogen fertilizer applications decreased bolting flowers increased in onion crop.

However, the experiment's findings in the Raya Azobo district revealed that there was no significant effect when the rate of mixed fertilizer and vermicompost was increased

from the lowest to the maximum level (Table 3 and Appendix Table 2). The weather condition difference in these two districts might be a reason behind the variation in the number of bolting flowers.

Since flower bolting in plants is one of the physiological disorders the essential plant nutrients in vermicompost NPSZn fertilizer assist onions in carrying out important physiological functioning properly, which reduces flower bolting and encourages healthy plant development without flower bolting.

In contrarily, the findings of Lemma and Shemelis (2003), who claimed that, integrated treatment revealed that the minimal bolting percentage was two percent and that the variety and environmental factors had a significant impact on the bolting flower percentage.

Onion bulb size diameter (mm)

As a result of the combined application of vermicompost and NPSZn fertilizer, onion bulb size diameter greatly increased in both districts as compared to the absolute control (Table 2 and 3) and (Appendix Table 1 and 2). Therefore, the application of 4.5 t ha⁻¹ VC + 50 kg ha⁻¹ NPSZn at Kilte-Awulaelo resulted in the largest equatorial bulb diameter (57.53 mm). Similar to this, at Raya Azobo district 4.5 t ha⁻¹ VC + 75 kg ha⁻¹ NPSZn resulted in the highest equatorial bulb diameter (56.40 mm). Nevertheless, the minimum was 45.07mm and 43.47mm in Kilte-Awulaelo and Raya Azobo districts respectively from absolute control (Table 2 and Table 3). A similar finding was reported by (Soni *et al.*, 2016) that the maximum equatorial diameter (5.62 cm), was recorded with a 50% recommended dose of NPK along with vermicompost 2.5 t ha⁻¹.

Increased photosynthetic activity, chlorophyll production, nitrogen metabolism and auxin production in the plants as a result of the combined application of organic and inorganic fertilizers improved bulb diameter. Additionally, vermicompost was known to produce chemicals that promote growth, which may have contributed to a greater bulb size. The study by Gnanamani and Vijayalakshmi (2023) indicated that the vermicompost can be utilized effectively for sustainable crop production.

Bulb dry matter content (%)

In both districts, the shared application of vermicompost and blended fertilizer had no noticeable effect on onion bulb dry matter content (Table 2 and 3) and (Appendix Table 1 and 2). In general, it was noted that the results from the Kilte-Awulaelo district had a higher dry matter content than those from the Raya Azobo district. The present dry matter content variation might be due to the weather condition difference between the two districts and onion favor a cool temperature (Kilte-Awulaelo) rather than a warm temperature (Raya Azobo) for weight development.

Tekalign *et al.* (2012), in contrast to this conclusion, reported a 4% decrease in onion dry matter as a result of applying 138 kg N ha⁻¹ in comparison to the control. Similar findings were made by Alemu *et al.* (2016) on garlic bulbs,

who found that applying vermicompost at a rate of 5 t ha⁻¹ over the control enhanced the dry matter content by 8.13%.

Mean bulb weight (g)

The analysis of variance revealed that the effect of vermicompost and NPSZn fertilizer (P<0.05) had highly significant effects on onion mean bulb weight in both districts (Table 4 and 5) and (Appendix Table 3 and 4). The maximum mean bulb weight of (125.87 g) was obtained from 4.5 t ha⁻¹ VC+50 kg ha⁻¹ NPSZn at Kilde-Awulaelo district,

whereas the minimum mean bulb weight (89.93 g) was found in absolute control. The maximum mean bulb weight (106.33 g) was recorded in the Raya Azobo district, where 4.5 t ha⁻¹ VC + 75 kg ha⁻¹ NPSZn were applied, whereas the lowest mean bulb weight (67.19 g) was in the Kilde-Awulaelo district when absolute control was used. In both districts increasing the rate of vermicompost and NPSZn fertilizer significantly increased mean bulb weight.

This might be because, in addition to macronutrients, vermicompost also contains several micronutrients that

Table 4: Effects of vermicompost and NPSZn fertilizer on mean bulb weight, marketable bulb yield and unmarketable bulb yield at Kilde Awulaelo District.

Treatment	combinations	Mean bulb weight (g)	Marketable bulb yield (t ha ⁻¹)	Unmarketable bulb yield (t ha ⁻¹)
T ₁	Absolute Control	89.93 ^f	23.76 ^f	0.55 ^{ab}
T ₂	NPSZn 100 kg ha ⁻¹ (FP)	111.8 ^{cd}	40.46 ^c	0.53 ^{ab}
T ₃	6 t ha ⁻¹ VC	114.2 ^{bcd}	42.57 ^{bc}	0.35 ^{bc}
T ₄	4.5 t ha ⁻¹ VC + 25 kg ha ⁻¹ NPSZn	110 ^{cd}	32.47 ^d	0.48 ^{bc}
T ₅	4.5 t ha ⁻¹ VC + 50 kg ha ⁻¹ NPSZn	125.87 ^a	51.67 ^a	0.31 ^c
T ₆	4.5 t ha ⁻¹ VC + 75 kg ha ⁻¹ NPSZn	124.6 ^{ab}	50.18 ^a	0.32 ^c
T ₇	3 t ha ⁻¹ VC + 25 kg ha ⁻¹ NPSZn	104.73 ^{de}	29.53 ^{def}	0.49 ^{bc}
T ₈	3 t ha ⁻¹ VC + 50 kg ha ⁻¹ NPSZn	114.6 ^{abcd}	45.86 ^{abc}	0.39 ^{bc}
T ₉	3 t ha ⁻¹ VC + 75 kg ha ⁻¹ NPSZn	117.4 ^{abc}	47.5 ^{ab}	0.36 ^{bc}
T ₁₀	1.5 t ha ⁻¹ VC + 25 kg ha ⁻¹ NPSZn	95.8 ^{ef}	24.82 ^{ef}	0.53 ^{ab}
T ₁₁	1.5 t ha ⁻¹ VC + 50 kg ha ⁻¹ NPSZn	103.53 ^{de}	33.42 ^d	0.47 ^a
T ₁₂	1.5 t ha ⁻¹ VC + 75 kg ha ⁻¹ NPSZn	103.93 ^{de}	30.33 ^{de}	0.4 ^{bc}
LSD (P<0.05)		11.67 ^{***}	6.28 ^{***}	0.2 [*]
CV		6.31	9.89	26.59

Note: FP = (Farmers practice), the same letter within a column are not significantly different indicated by * and ** significant (P<0.05), highly significant (P<0.01) respectively.

Table 5: Effects of Vermicompost and NPSZn fertilizer on mean bulb weight, marketable bulb yield and unmarketable bulb yield at Raya Azobo District.

Treatment	combinations	Mean bulb weight (g)	Marketable bulb yield (t ha ⁻¹)	Unmarketable bulb yield (t ha ⁻¹)
T ₁	Absolute Control	67.19 ^e	17.53 ^f	1.75 ^a
T ₂	NPSZn 100 kg ha ⁻¹ (FP)	75.65 ^{cde}	30.78 ^c	1.69 ^a
T ₃	6 t ha ⁻¹ VC	81.33 ^{bcd}	28.57 ^{cd}	0.22 ^{ef}
T ₄	4.5 t ha ⁻¹ VC + 25 kg ha ⁻¹ NPSZn	82.83 ^{bcd}	25.44 ^{de}	0.22 ^{ef}
T ₅	4.5 t ha ⁻¹ VC + 50 kg ha ⁻¹ NPSZn	98.71 ^{abc}	39.22 ^{ab}	0.35 ^{de}
T ₆	4.5 t ha ⁻¹ VC + 75 kg ha ⁻¹ NPSZn	106.33 ^a	42.34 ^a	0.16 ^f
T ₇	3 t ha ⁻¹ VC + 25 kg ha ⁻¹ NPSZn	72.08 ^{de}	25.01 ^{de}	0.53 ^c
T ₈	3 t ha ⁻¹ VC + 50 kg ha ⁻¹ NPSZn	100.25 ^{ab}	37.42 ^b	0.34 ^{de}
T ₉	3 t ha ⁻¹ VC + 75 kg ha ⁻¹ NPSZn	91.03 ^{abcd}	30.92 ^c	0.49 ^{cd}
T ₁₀	1.5 t ha ⁻¹ VC + 25 kg ha ⁻¹ NPSZn	71.1 ^{de}	20.94 ^{ef}	1.62 ^a
T ₁₁	1.5 t ha ⁻¹ VC + 50 kg ha ⁻¹ NPSZn	76.04 ^{cde}	19.96 ^f	1.33 ^b
T ₁₂	1.5 t ha ⁻¹ VC + 75 kg ha ⁻¹ NPSZn	79.59 ^{bcd}	25.65 ^{de}	1.28 ^b
LSD (P<0.05)		23.29 [*]	4.86 ^{***}	0.15 ^{***}
CV		16.55	10.06	10.7

Note: FP = (Farmers practice), the same letter within a column are not significantly different indicated by * and ** significant (P<0.05), highly significant (P<0.01) respectively.

contribute to the formation of bulb weight. Additionally, mycorrhizae, healthy bacteria and enzymes are all present in vermicompost and encourage growth and bulb weight. Singh *et al.* (2015) stated that the increase in bulb weight is due to the increased uptake of nutrients and the buildup of sufficient photosynthesis. The increase in bulb weight might be ascribed to an increase in plant height, number of leaves produced and leaf length as a result of the greatest rate of nitrogen application (Kenea and Gedamu, 2018; Shedeed *et al.*, 2014; and Jayathilake *et al.*, 2002).

Marketable bulb yield

Marketable bulb yield was highly significant and had varied responses for the combined application of vermicompost and NPSZn fertilizer in both districts (Table 4 and 5) and (Appendix Table 3 and 4). The maximum marketable bulb yield (51.67 t ha⁻¹) was obtained from 4.5 t ha⁻¹ VC+50 kg ha⁻¹ NPSZn followed plot received 4.5 t ha⁻¹ VC+75 kg ha⁻¹ NPSZn fertilizer 50.18 t ha⁻¹ in Kilte-Awulaelo district. Nevertheless, the minimum marketable bulb yield (23.76 t ha⁻¹) was obtained in absolute control. At Raya Azobo, district the maximum marketable bulb yield (42.34 t ha⁻¹) was obtained from the application of 4.5 t ha⁻¹ VC+75 kg ha⁻¹ NPSZn, whereas the lowest (17.53 t ha⁻¹) was recorded from absolute control.

The present study is supported by Balemi *et al.* (2007) who found that the marketable bulb yield significantly

increased as the rate of the combined application increased. Similarly, the highest marketable yield (35.13 t ha⁻¹) of onion bulb yield was obtained from the application of 5 t ha⁻¹ VC + 50% N, While, the lowest value of marketable bulb yield (18.48 t ha⁻¹) was recorded from control.

Yoldas *et al.* (2011) and Mogren *et al.* (2008), on the other hand, revealed that integrated soil fertility management is not always the most important factor for optimum marketable onion yield; rather, soil structure conducive to water retention and sufficient porosity to allow for bulb expansion play important roles.

Unmarketable bulb yield (t ha⁻¹)

The unmarketable bulb yield was significantly influenced by the application of different rates of vermicompost and blended fertilizer in both districts (Table 4 and 5) and (Appendix Table 3 and 4). At Kilte-Awulaelo the highest unmarketable bulb yield (0.55 t ha⁻¹) was recorded from absolute control followed by NPSZn 100 kg ha⁻¹ as a value of 0.55 t ha⁻¹. The minimum unmarketable yield (0.31 t ha⁻¹) was recorded from the plot received 4.5 t ha⁻¹ VC+50 kg ha⁻¹ NPSZn fertilizer.

At Raya Azobo district the maximum unmarketable bulb yield (1.75 t ha⁻¹) was recorded from absolute control followed by 100 kg ha⁻¹ NPSZn fertilizer which was 1.69 t ha⁻¹. However, the lowest (0.16 t ha⁻¹) was obtained from 4.5 t ha⁻¹ VC+75 kg ha⁻¹ NPSZn application. Furthermore, at

Appendix Table 3: Mean squares of analysis of variance for marketable bulb yield, unmarketable bulb yield, total bulb yield, dry matter content and bulb size distribution at Kilte-Awulaelo districts.

Source of variation	DF	Mean square values						
		MBY	UMY	TBY	DMC	Bulb size distribution		
						L	M	S
Trt	11	293.15***	0.04*	288.49***	1.55 ^{ns}	211.95***	78.62***	53.87**
Error	24	13.9	0.01	13.91	2.63	27.84	14.81	14.71
Total	35	-	-	-	-	-	-	-
CV		9.89	26.6	9.78	6.00	9.40	13.21	26.00

Where, ns= Non-significant, * and ** indicates significant difference at probability levels of 5% and 1%, respectively. Trt = Treatment, DF = Degree of freedom, MBY = Marketable bulb yield; UBY = Unmarketable bulb yield, TBY = Total bulb yield, DMC = Dry matter content, L = Large, M = Medium, S = Small.

Appendix Table 4: Mean squares of analysis of variance for marketable bulb yield, unmarketable bulb yield, total bulb yield, dry matter content and bulb size distribution at Raya Azobo Districts.

Source of variation	DF	Mean square values						
		MBY	UMY	TBY	DMC	Bulb size distribution		
						L	M	S
Trt	11	184.54***	1.23***	165.91***	2.92 ^{ns}	1021.32***	28.54	996.35**
Error	24	8.31	0.01***	8.29***	4.18 ^{ns}	184.69***	161.06 ^{ns}	256.94**
Total	35	-	-	-	-	-	-	-
CV		10.06	10.7	9.77	9.81	18.43	20.38	25.69

Where, ns= Non-significant, * and ** indicates significant difference at probability levels of 5% and 1%, respectively. Trt = Treatment, DF = Degree of freedom, MBY = Marketable bulb yield; UBY = Unmarketable bulb yield, TBY = Total bulb yield, DMC = Dry matter content, L = large, M = Medium, S=Small.

Raya Azebo, unmarketable bulb yield was significantly decreased by 90.86% from the application rate of 4.5 t ha⁻¹ VC+75 kg ha⁻¹ NPSZn application to the unfertilized and 100 kg ha⁻¹ NPSZn fertilizer.

Many of the nutrients in vermicompost are changed to forms that are more easily taken by plants during the processing of the various organic wastes by earthworms, such as nitrate or ammonium nitrate, exchangeable phosphorous and soluble potassium, calcium and magnesium (Suthar and Singh, 2008).

Vermicompost is an organic fertilizer that is rich in macro-and micronutrients, as well as magical growth boosters and defenders like “nitrogen-fixing bacteria” and “mycorrhizal fungi”. The application of imbalanced and unintegrated nutrient management may contribute to the increase in unmarketable bulb production caused by inadequate soil fertilization. Furthermore, insufficient application of organic and inorganic fertilizers to the soil causes nutritional shortages and undersized, decaying, thick-necked and poor-yielding onion bulbs.

Total bulb yield (t ha⁻¹)

The maximum total bulb yield (51.99 t ha⁻¹) was obtained in 4.5 t ha⁻¹ VC+50 kg ha⁻¹ NPSZn application, while the minimum total bulb yield (24.31 t ha⁻¹) was recorded in absolute control at Kilte-Awulaelo district (Table 4). The increment of total bulb yield gained from the combined application was 53.2% higher as compared to the absolute control. Nevertheless, at Raya Azobo, the highest onion total bulb yield of 42.49 t ha⁻¹ was obtained from 4.5 t ha⁻¹ VC+75 kg ha⁻¹ NPSZn which was followed by the application of 4.5 t ha⁻¹ VC+50 kg ha⁻¹ NPSZn (39.56 t ha⁻¹) of total bulb yield whereas, the minimum (19.28 t ha⁻¹) was recorded from the absolute control (Table 5).

According to Chandan *et al.* (2015) and Bisetegn (2016), increasing the use of organic manure boosts vegetable crop yield and quality. Therefore it could be due to existing essential plant nutrients deficiency and increasing the rate of vermicompost significantly increased onion total bulb yield at both districts. Integrated nutrient management will not only help to improve the economic return and revenue generation of the farmers but also lower the growing onion market prices in the country (Mohanty *et al.*, 2024).

In contrast to this study, Rathod *et al.* (2009) and Warman (2005) and observed that composting onions using a range of organic materials did not improve bulb yield. Similarly, Vidigal *et al.* (2010) reported that higher compost application can negatively affect onion bulb yield and sometimes result in excessive phosphorus and potassium accumulations in the soil. Another study by Lee *et al.* (2018) revealed that despite the positive effects of compost on onion, different organic fertilizers can have variable quality and have different impacts on crop productivity. Vermicomposting also the increased crop production in vermicompost treated soil (Kapila *et al.*, 2021).

CONCLUSION

The effect of vermicompost and NPSZn fertilizer on different growth and yield parameters of onion was studied to identify the optimum rate of vermicompost and NPSZn fertilizer for best onion bulb production. Almost all the measured onion bulb growth and yield parameters showed differences in response to the combined application of vermicompost and NPSZn fertilizer. Most growth and yield parameters were significantly influenced by variable rates of vermicompost and NPSZn fertilizer at both the Kilte-Awulaelo and Raya Azobo districts. Onion bulb production can be optimized by using selective combinations of organic and inorganic fertilizers. The result of the current study delivers straightforward information for further research and development efforts in soil fertility management for sustainable utilization of the soil resources in the districts for improvement of onion bulb production.

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Declaration

Authors' contributions

Tesfay Teklehaimanot Conceptualize, collected the data, analyzed and write the paper Ambachew Zerfu and Meresa Shumeye also conceptualize and analyzed the data. Ambachew Zerfu prepared and edited the manuscript. All authors read and approved the final manuscript.

Data availability statement

Data used in this study will be made available by the corresponding author on request.

Consent for publication

We have agreed to submit to the Agriculture Reviews and approved the manuscript for submission.

Ethics approval

The study is not conducted on human and animal.

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Competing interests

The authors declare that they have no competing interests.

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