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Evaluating the Influence of Vermi-Compost and NPS Fertilizer on Yield and Yield Components of Potato (Solanum tuberosum L.) in Bale Highland, Southeast Ethiopia

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Abstract

Potato is a high-yielding potential crop grown for its high nutritional value but constrained with low soil fertility. *This study aimed to evaluate the combined effects of vermi-compost and NPS (Nitrogen, Phosphorus, and Sulfur) fertilizers on the yield and yield components of the Gudane cultivar. A field experiment was conducted using a randomized complete block design with a factorial arrangement, comprising three levels of NPS (50, 100, and 125 kg ha⁻¹) and four levels of vermi-compost (0-, 2.5-, 5-, and 10-ton ha⁻¹), replicated three times. Key parameters assessed included plant height, total tuber yield, number of tubers per plant, average tuber weight, and tuber diameter. Results indicated significant improvements in yield and related components with the application of 5-ton ha⁻¹ of vermi-compost combined with 100 kg ha⁻¹ of NPS fertilizer, particularly at the Dinsho site, which demonstrated superior productivity compared to Sinana site. The findings underscore the efficacy of integrating vermi-compost with NPS fertilizer in enhancing growth and yield parameters of potato. However, further investigations are recommended to establish optimal application rates exceeding 5 ton ha⁻¹ of vermi-compost, taking into account variations in soil type and site conditions for maximizing crop response*

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1. Introduction

Potato (*Solanum tuberosum* L.) is a globally important crop, ranking third in world consumption after wheat and rice (Yourtchi, 2013; Habtamu *et al.*, 2012). Its high productivity per unit area made potatoes an ideal food crop that provides energy, nutrients, and quality protein, for rapidly increasing world population (Bezabih & Mengistu, 1989). In Sub-Saharan Africa, particularly Ethiopia, potato production is rapidly increasing due to favorable agro-ecological conditions (Haverkort, 2012; Borgal et al., 1980; Corcoran, 2014). According to the estimates of International Potato Institute, Ethiopia is considered more suitable and has highest potential for large scale potato production than other countries in Africa, with ca.70% of its arable land being suitable for potato cultivation (Corcoran, 2014).

Soil health, including physical, chemical, and biological properties is crucial for crop productivity (Dutta, 1986). Accordingly, proper nutrient management involving the use of manures and fertilizers enhances potato yield and quality. Organic farming practices, especially the use of vermi-compost, offer a sustainable alternative by improving soil structure, increasing microbial activity, and providing essential nutrients like NPKS (Hala & Claus, 2008; Abdullah, 2008; Maria et al., 2011; NeBambi *et al.*, 2008). Vermi-compost is also economically viable and environmentally friendly (Saikia & Rajkhowa, 1998; Alam et al., 2007; Canellas et al., 2002).

With rising fertilizer costs and limited availability in Ethiopia (Aryal et al., 2021), organic alternatives such as vermi-compost become crucial for smallholder farmers. Moreover, the Ethiopian government is promoting eco-friendly farming practices for sustainable food security (NIER, 2021; Bello, 2008). Although combining vermi-compost with NPS fertilizers could enhance potato yield, this interaction has not been thoroughly studied in regions like the Bale highlands of Ethiopia. Therefore, this study was conducted to determine optimal application rates and interactions of vermi-compost and NPS for maximizing potato productivity.

2. Materials and Methods

2.1. Description of the Experimental Sites

The experiment was conducted at two sites, namely Sinana (Madda walabu University) and Dinsho districts. Sinana district is located 7º 7′ N latitude and 40º 10′ E longitude and found 430 km southeast of Addis Ababa in the highlands of Bale Zone. The area is situated at an altitude of 2400 meters above sea level with an average annual rainfall range from 823-1567mm. The average monthly maximum and minimum temperature are 24.2^0Cand 9.4^0C,

respectively. The area is categorized as highland and has a well-drained pellic vertisol with slightly acidic (pH = 6.2). Dinsho on the other hand is located 400 km southeast of Addis Ababa. The area is situated at 6^{o} 11'N and 40^{O} 3'E and 2530 meters above sea level. The average annual rainfall ranges from 880-1100mm and in cool sub humid agro climatic zone of Bale .The average monthly minimum and maximum temperatures are 7.1^{0}C and 24.8^{0} C, respectively. The area is categorized as a highland agro-climatic zone (BZAO unpublished, 2011).

2.2 Experimental Design and Procedures

The experiment was conducted on potato variety 'Gudane' for its high yielding and disease resistance. The experimental design was RCBD in factorial arrangement with three replications. Experimental treatment includes NPS fertilizer with three levels: (50, 100 and 125 kg/ ha) and vermi-compost with four levels (0, 2.5, 5, and 10 ton/ ha). A total combination of 36 experimental plots on the total experimental site of 222.95m^2 (34.3mx6.5m) and 30 gm of tuber potato with spacing 30 cm * 75 cm between plants and rows were used. NPS was used as inorganic fertilizer sources and well decomposed vermi-compost on dry bases were used as source of organic fertilizers. Well decomposed vermi-compost were applied during planting time to their respective plots immediately while, NPS were applied three times in which one third at the time of planting, the other one third at two weeks after emergence and the remaining one third at the initiation of flowering. Fertilizer was placed slightly below the seed tubers to avoid contact between the seed and fertilizer. The first earthing-up was done when the potato plant reaches 10-15cm high so that the lower part was covered with loose soil in which the tubers can develop. The first ridging matches with the first weed control by hand as required whereas second ridging was done after potato tubers have started to break the soil to avoid greening of tubers, suppress weed and control tuber moth. For Late blight diseases protection, Ridomil Gold M.Z 64 % W.P at a rate of 3 kg/ha mixing with 400 liters of water was applied two times repetitively. Soil moisture was kept at adequate levels to prevent water deficit and wilting. Traits such as plant height, tiller number per plant, total tuber yield, number of tubers per plant, average tuber yield and tuber diameter were measured.

2.3 Statistical Analysis

All measured data were subjected to analysis of variance (ANOVA) using the general linear model of statistical analysis SAS computer package version 9.11 (SAS Institute Inc, 2003 version). All significant pairs of treatment means were compared using Least Significant Difference (LSD) test at the 5% significance level (LSD 5%).

3. Results and Discussion

3.1 Phenological parameters

3.1.1 Effect of vermi-compost and NPS fertilizer on plant height

The plant height was significantly affected by the treatments at different growth periods (Table 1). The plant height generally

increased up to 5ton/ha vermi-compost and 100kg/ha NPS fertilizer while it decreases as the level of vermin-compost and NPS fertilizer increases to 10ton/ha and 125Kg/ha, respectively under both experimental locations. The plant height was significantly influenced by different treatments but there was minimal difference. The plant height at harvesting stage ranges from 50.6 to 77.67cm. The highest plant height (77.67cm) was found with vermi-compost 5ton and 100kg NPS followed by 10ton vermi-compost and 125Kg NPS in Dinsho and Sinana site. The second plant height (69.63cm) was recorded in vermi-compost 2.5-ton and 50kg NPS followed by (68.10 cm) under 5ton plus 50kg NPS. Since Dinsho district relatively high potential area in terms of potato productivity compared to Sinana district which is concomitant with the current findings. In both sites the lowest plant height was recorded in the 0 ton/ha (control) VC and 50kg NPS level, respectively. Since the shortage of nutrient elements is one of the effective factors on plant height, it seems that why led to lowest height under 0-ton VC and 50kg NPS and might be due to site specific factors like soil pH. The results agree with the findings of (Mojtaba. *et al.*,2013), who stated that the effect of nitrogen fertilizer and vermi-compost, had significant impact on plant height of potato.

Table 1. Effect of vermi -compost and NPS fertilizers on plant height of potato

VC (ton)	Dinsho Site		NPS Kg	Sinana Site		NPS Kg
	50kg/ha	100kg/ha	125kg/ha	50kg/ha	100kg/ha	125kg/ha
0	50.67^{C}	65.67^{ABC}	53.3^{C}	54.833^{C}	56.40^{BC}	64.20^{ABC}
2.5	52.3^{C}	71.0^{AB}	57.3^{BC}	69.63^{A}	65.40^{AB}	68.10^{A}
5	58.0^{BC}	77.67^{A}	6.0^{ABC}	65.967^{A}	61.43^{ABC}	65.90^{A}
10	71.67^{AB}	72.67^{AB}	77.3^{A}	63.867^{ABC}	61.40^{ABC}	56.40^{BC}
LSD	15.831			9.42		
CV	14.50			8.86		

In a column, figures having same letter(s) do not differ significantly at 5% level of significance

The increase in height due to increased application rate of the combined NPS and vermi-compost could be attributed to the fact that vermi-compost contains a good range of additional essential micronutrient other than NPS fertilizers, required for healthy plant growth (Surindra, 2009) and Nitrogen from vermi-compost as well as the inorganic Nitrogen application is one of the important building blocks of amino acids (-NH2), where they link together and form proteins and make up metabolic processes required for plant growth (Kocaman *et al.*, 2024).

3.1.2 Effect of Vermi-Compost and NPS Fertilizer on Tiller Number

The tiller numbers were significantly influenced by the application of different

treatments (Table 2). The number of tillers ranged from 5.86 to 17.66 in both sites. The highest numbers of tiller were produced under the application of vermi-compost 10ton plus NPS 50kg in Dinsho and of vermi-compost 5ton plus NPS 50kg in Sinana site, respectively. The plant having no VC fertilizer produced the minimum number of tillers in both sites. The finding showed that the application of a minimum vermi-compost plus NPS have had a considerable impact on tiller numbers of potatoes compared to 0kg vermi-compost. Alam *et al.,* (2007) stated that the maximum number of main stems (3.63) per hill was obtained by the application of vermi-compost (10 t/ha) + NPS (50% or 100%). Accordingly, (Bongkyoon 2004) also mentioned that the number of stems/plants tended to increase in the plots where 8-10 t/ha vermi-compost were applied.

Table 2. Effect of vermi -compost and NPS fertilizers on Tiller number

VC ton	Dinsho Site NPS in kg			Sinana Site NPS in kg		
	50	100	125	50	100	125
0	13.000^{BCDE}	10.333^{E}	10.667^{DE}	5.86^{D}	7.13^{D}	7.63^{D}
2.5	15.000^{ABC}	10.333^{E}	12.000^{CDE}	8.03^{CD}	8.86^{BCD}	9.23^{BCD}
5	16.000^{AB}	15.000^{ABC}	12.667^{BCDE}	13.467^{A}	13.3^{A}	12.33^{AB}
10	17.667^{A}	12.333^{CDE}	14.000^{BCD}	8.46^{BCD}	11.73^{ABC}	7.633^{D}
LSD	3.5830			3.92		
CV	15.97			24.45		

In a column, figures having same letter(s) do not differ significantly by at the 5% level of significance.

3.1.3 Effect of Vermi-Compost and NPS Fertilizer on Average Tuber Yield

The Average tuber yield of potato was increased significantly because of vermi-compost and NPS fertilizers (Table3). The Average tuber yield in different treatments ranged from 724.7 to 1069 g. The highest yields observed in the level of vermi-compost 5ton + 100kg NPS followed by vermi-compost 2.5ton + 100kg NPS in Dinsho site while in Sinana vermi-compost 10ton + 100kg NPS followed by 5ton + 100kg NPS. It was indicated that the increasing amounts of applications of both fertilizers produced a higher tuber yield. But NPS at the rate of 100 kg with vermi-compost 5ton produced statistically similar tuber yield. The lowest tuber yields 724.7) were found in 0kg VC and 50kg NPS. The different doses of vermi-compost (2.5, 5, 10ton) gave higher yield than 0kg vermi-compost. The results showed that 125 NPS with 5kg vermi-compost is more efficient than other treatment which indicates that 100 percent inorganic fertilizers with 5ton vermi-compost produced higher yield of potato in Dinsho site and 100 percent inorganic fertilizers with 10ton VC in Sinana site. It was also concluded that the combination of vermi-compost with

chemical fertilizer increased the availability of essential soil micronutrients and promotes microbial population, which ultimately promotes the plant growth and production at sustainable basis (Surindra, 2009).

Table 3. Effect of vermi -compost and NPS fertilizers on Average tuber yield gram

VC ton	Dinsho Site NPS Kg			Sinana Site NPS Kg		
	50	100	125	50	100	125
0	724.7 ^{F}	800.6^{EF}	776.4^{EF}	768.7^{D}	770.3^{D}	771.3^{D}
2.5	835.7^{CDEF}	813.7 ^{DEF}	1066.3^{AB}	847.7^{CD}	833.0^{CD}	859.1^{CD}
5	884.0^{BCEF}	1000.3^{ABC}	1069.0^{A}	865.0^{CD}	1018.3^{AB}	1034.3^{AB}
10	992.7^{ABCD}	856.3 ^{CDEF}	937.7^{ABCDE}	901.5^{BCD}	926.7^{BC}	1136.7^{A}
LSD	183.85			136.53		
CV	12.11			9.01		

In a column, figures having same letter(s) do not differ significantly at the 5% level of significance

3.1.4 Effect of vermi-compost and NPS fertilizer on marketable yield

Vermi-compost and NPS fertilizer significantly influenced total, marketable tuber yield (Table 4). Application of vermi-compost with the rate of 10ton/ha significantly increased total marketable tuber yield by 7kg compared to without application of vermi-compost. The marketable yield is the weight of tubers which are free from diseases, insect pests, and greater than or equal to 25 g in weight. This shows that the optimum total and marketable fresh tuber yield was already attained at vermi-compost with the rate of 10ton/ha and application beyond that level was supra-optimal and unnecessary while application of NPS fertilizer more than 100kg/ha unnecessary in this particular parameter. The increase in number of marketable tuber yield with applied vermi-compost and NPS was associated with decrease in the number of small size tubers due to increase in the weight of individual tuber. Also, this might be the positive interaction and complementary effect of vermi-compost and NPS in affecting and increasing marketable tuber yield of potato in the study area.

This result is in line with the findings of Gezachew (2006) who showed that the interaction effect of compost and NP fertilizers significantly increased total and marketable number of potatoes. Also, the finding indicated that potatoes are highly yielding and perishable agricultural products. Hence, it has to be sold or stored in an appropriate store within a short period of time after the harvest. For this user should use all sorts of markets such as farm gates, local and city markets either in wholesale consumers or retail means.

Table 4. Effect of vermi -compost and NPS fertilizers on marketable yield gram

VC ton/ha	Dinsho site	NPS kg/ha.	Sinana site	NPS kg/ha.

	50	100	125	50	100	125
0	296.4^{E}	10.33^{E}	14.00^{BCD}	9.23^{B}	10.10^{B}	9.500^{B}
2.5	15.00^{ABC}	10.3^{E}	11.67^{DE}	10.23^{B}	9.53^{B}	10.76^{B}
5	16.00^{AB}	15.0^{ABC}	12.67^{CDE}	15.90^{A}	16.10^{A}	11.46^{B}
10	17.667^{A}	12.33^{CDE}	12.00^{CDE}	12.63^{AB}	15.28^{A}	15.467^{A}
LSD	3.2747			3.5814		
CV	14.72			17.36		

In a column, figures having same letter(s) do not differ significantly at the 5% level of significance

3.1.5 Effect of vermi-compost and NPS fertilizer on unmarketable yield

Vermi-compost and NPS fertilizer significantly influenced total, unmarketable tuber yield reduction (Table 5). Unmarketable tubers yield significantly decreased by 0.02kg in Dinsho and 0.33kg/ha in Sinana at an application rate of 5ton/ha vermi-compost and 100kg/ha NPS.

Table 5. Effect of vermi -compost and NPS fertilizers on unmarketable yield

VC ton/ha	Dinsho site NPS kg/ha			Robe site NPS kg/ha		
	50	100	125	50	100	125
0	3.33 ^{AB}	4.33^{A}	0.33^{DE}	4.67^{A}	3.667^{AB}	2.33^{BC}
2.5	2.67^{BC}	2.67^{BC}	0.33^{DE}	2.00^{BC}	2.33 ^{BC}	0.333 ^{C}
5	1.67^{CD}	2.33^{BC}	0.02^{E}	1.67^{BC}	1.00^{C}	0.33 ^{C}
10	2.33^{BC}	0.67^{DE}	1.33^{CDE}	2.333BC	1.67 ^{BC}	1.67^{BC}
LSD	1.6478			2.275		
CV	53.08			67.84		

In a column, figures having same letter(s) do not differ significantly at the 5% level of significance

A significant decrease in unmarketable tuber potato might be due to effect of vermi-compost. An important feature of vermi-compost is that, during the processing of the various organic wastes by earthworms, many of the nutrients that it contents are changed to forms that are more readily taken by plants such as nitrate or ammonium nitrate, exchangeable phosphorous and soluble potassium, calcium and magnesium (Suthar and Singh, 2008a).

3.1.6 Effect of vermi-compost and NPS fertilizer on tuber diameter

The effect of vermi-compost and NPS fertilizer were significant ($P \leq 0.05$) on tuber diameter (Table 6). Results illustrate that the increasing vermi-compost rate up to 5ton/ha increased tuber diameter. The highest and lowest amount of tuber diameter was achieved at 5ton/ha and 0 ton/ha with 16.4 and 12.67 cm respectively (Table 6). Also, it was observed that the application of NPS fertilizer led to an increase in tuber diameter. There were no significant Differences between 5ton/ha and 10ton/ha treatments. Padmavathiamma*et al*, 2008, showed that the application of vermin-compost significantly improved the qualitative and quantitative characteristics of cassava and led to better absorption of nutrition elements

in these plants. The finding in line with results of Mojtaba *et al.,* (2013), who illustrate that increasing nitrogen rates up to 150 kg per/ha and vermi-compost up to 12 ton/ha increased tuber diameter significantly.

Table 6. Effect of vermi -compost and NPS fertilizers on tuber diameter in cm

VC	**Dinsho Site**	**NPS Kg**		**Sinana Site**	**NPS Kg/ha**	
ton/ha	50	100	125	50	100	125
0	12.67^{DE}	13.0^{E}	13.58^{E}	12.867^{DE}	13.4^{CDE}	11.83^{E}
2.5	16.3^{DE}	17.96^{CD}	18.33^{BCD}	13.8^{BCDE}	$14.9A^{BCDE}$	13.167^{CDE}
5	16.4^{DE}	22.70^{AB}	22.83^{A}	18.167^{ABC}	17.6^{ABCD}	18.927^{AB}
10	15.43^{DE}	18.16^{CD}	21.33^{ABC}	19.37^{A}	15.7^{ABCDE}	17.057^{ABCD}
LSD	4.49			5.21		
CV	15.2			19.86		

In a column, figures having same letter(s) do not differ significantly at the 5% level of significance

3.1.7 Effect of vermi-compost and NPS fertilizer on total tuber yield

The effect of vermi-compost and NPS fertilizer were significant ($P \leq 0.05$) on total tuber yield (Table 7). Tuber total yield demonstrated numerical change by increasing vermi-compost rates up to 5ton/ha. The highest and lowest amount of the trait was found at 125kg ha^{-1} NPS and 0ton/ha VC with 22.8 and 19.37, 13.8 and 11.8 kg under the two sites, respectively (Table 7). Also, it was seen that application NPS fertilizer increased the amount of tuber total weight while there was no significant difference between 50kg/ha and 100 kg/ha treatment. The highest and lowest amounts were gained at application of 100kg NPS fertilizer along with the application of 5ton vermi-compost. This result is supported by that of (Sibale and Smith, 1997) who reported a significant increase in potato tuber yield components with the application of organic manure. The increased total tuber yield could be due to the role of vermi-compost which is known to contain micronutrients apart from major nutrients. Besides this, vermi-compost has been reported to contain several plant growth promoters, enzymes, beneficial bacteria and mycorrhizae (Gupta, 2005). According to the available reports, consumption of vermi-compost in all treatments increased the total number of tubers compared to control. The highest amount of tuber fresh weight was found 12-ton ha-1 while the lowest one belonged to control (Mojtaba *et al.*,2013).

Table 7. Effect of vermi -compost and NPS fertilizers on total tuber yield (qt/ha)

VC	Dinsho Site	NPS in kg/ha		Sinana Site	NPS in Kg/ha	
to/ha	50	100	125	50	100	125
0	441.7^{D}	465.3^{D}	590.8^{ABCD}	328.6^{ABC}	331.4^{ABC}	289.8^{C}
2.5	520.8^{BCD}	611.1^{ABCD}	597.2^{ABCD}	342.5^{ABC}	352.8^{ABC}	314.81^{BC}
5	709.2^{A}	668.05^{AB}	694.7^{AB}	384.2^{A}	344.4^{ABC}	374.1^{AB}
10	655.3^{ABC}	481.1^{CD}	471.6^{CD}	353.7^{ABC}	338.9^{ABC}	324.1^{ABC}

LSD	67.158	2.3072
CV	19.14	11.13

In a column, figures having same letter(s) do not differ significantly at the 5% level of significance

According to Balemi, 2012, supplementing 66.6% of the recommended inorganic fertilizers with 20 t ha-1 farm yard manure was sufficient to significantly increase the total tuber yield over the control in vertisol whereas the quantity of FYM that should supplement the same level of inorganic NP fertilizers in nitosol to significantly increase the tuber yield over the standard control was 30 t ha-1which could probably the physico-chemical characteristics of vertisol such as drainage, and N and P mineralization rate responded more favorably even to lower farmyard manure application compared to nitosol. Since, vermi-compost works as a 'slow-release fertilizer' and 'protect plants' against pest & diseases. With their continued application, the 'organic nitrogen' and other nutrients in compost tend to be released at constant rate from the accumulated 'humus' and the net overall efficiency of NPK over a period of years is considerably greater than 50 percents of the chemical fertilizers. Apparently, it is both earthworms and their excreta (vermi-cast) that plays a combined role in growth promotion. Worms & microbes secrete growth promoting plant hormones 'gibberlins', auxins' and 'cytokinins', help mineralize the nutrients and make them 'bioavailable' (Anonymous, 2009).

4. Conclusions

The effect of integrated application of vermi-compost and NPS fertilizers on growth, yield and yield components was studied in a field experiment conducted during 2019-20 main cropping season with the objective of determining the effect of vermin-compost and NPS fertilizers on potato yield and yield components and evaluating the interaction effect of vermi-compost and NPS fertilizer on yield components of potato. Among the different dosages of vermi-compost applied there has been a significant improvement in yield and yield components of potato amended with vermi-compost at 5ton per ha and 100kg/ha NPS. The overall productivity of potato under the two sites, especially in Dinsho, was significantly greater in site treated with vermi-compost at 5ton per ha and 100kg/ha NPS fertilizer. The results of this study indicated that the application of vermi-compost in combination with NPS fertilizer has positive effects on growth, yield and yield related parameters of tuber potato. It should be underscored that with the application of only 5ton/ha of vermi-compost, the amount of the inorganic fertilizers required can be substantially reduced without compromising yield. The highest growth, yield and yield component of tuber obtained at 5ton/ha level of vermi-compost. However, to determine the optimum crop response and treatment level by emphasizing the site soil difference, further investigation is recommended with

the consideration of more than 5ton/ha levels of vermi-compost and soil types.

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No potential conflict of interest was reported by the author(s).

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