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Effects of Vermicompost and NPS Fertilizer rate on Yield and Yield Components of Highland Maize in Vertisol Ambo

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ABSTRACT

Integrated soil fertility management using organic and inorganic fertilizer is recognized as absolute soil fertility management aims to increase yield, a better option in improving agronomic efficiency, providing a more balanced supply of nutrients and saving cost of production. Considering importance integrated soil fertility management for crop production an experiment comprised of eleven sole and integrated nutrient management practices was conducted on smallholder farmers field around Ambo for highland maize in laid in a randomized block experimental design with three replications. Yield and yield components of highland maize variety (Wenchi) was significantly affected with sole and integrated use of vermicompost and NPS fertilizer rate. Significantly higher (6187 kg ha^{-1}) was obtained with application of 92/69/30 kg NPS ha^{-1} followed by (5193 kg ha^{-1}) with 50:50 vermicompost based on N equivalency and NPS fertilizer rate. Application of 92/69/30 kg NPS ha^{-1} gave the highest net return of EB 32265 with highest marginal rate return of 713 % followed by net return of EB 27167 and marginal rate return of 295 % for highland maize production was obtained from application of 50:50 % recommended NPS with vermicompost based on N equivalency in Vertisols of Ambo. Therefore application of 92/69/30 kg NPS ha^{-1} and 50:50 % recommended NPS with vermicompost based on N equivalency produced better grain yield and economical feasible and recommended for highland maize production in Vertisol of Ambo and similar agro-ecologies.

Keywords: Highland maize, integrated soil fertility management, NPS, variety, vermicompost

INTRODUCTION

Maize (*Zea mays* L.) an important crop which has a wider adaptability to varied agroecological conditions worldwide (Roychowdhury et al., 2017). Maize may be called as the 'king of cereals' as because of its high genetic yield potential in productivity when it is compared with other cereals (Umesha et al., 2014, Shah and Wani, 2017); most important cereal amongst the cereals due to its highest genetic yield potential (Roychowdhury et al., 2017); a queen of cereals due to its great importance in human and animal diet, very efficient utilizer of solar energy and has immense potential for higher yield (Yadav et al., 2017). It is the most widely cultivated cereal crop in terms of area coverage (16.08%) and production (25.81%, 6491540.292 tons) in Ethiopia (CSA, 2016). Currently, maize is the commonly crop by smallholder farmers in highland areas of western Ethiopia since commencement of highland maize improvement program in 1998 at Ambo. However, the estimated average yields of maize for smallholder farmers in Ethiopia are about 3.2 t ha^{-1} (CSA, 2016), which is much lower than its productivity in industrialized countries such as USA which is 8 to 9 tons ha^{-1} (FAO stat, 2015). This might be due to growing below optimum management practices (Tolera et al., 2017); abiotic stresses (Ahmad et al., 2014); both biotic stress (diseases, pests, and lack of suitable varieties) and abiotic stresses (low soil fertility and lack of capital to purchase farm inputs) (Bello *et al*., 2010: Veiga *et al*., 2012). Yield gaps is multi-facetted but nearly always contains poor soil fertility conditions or poor soil management practices as an important component (Kone et al., 2011; Tittonell et al., 2013). The severe decline of soil fertility in Ethiopia is due to inappropriate cropping practices including monocropping, unbalanced nutrient application, continuous cultivation, removal of crop residues from the fields and suboptimal of fertilizer application (Tolera, 2016). Farmers fail to attain the yield potential of the improved varieties due to the decline in soil fertility in areas where maize is the dominant crop it is mainly mono-cropped (Mosisa *et al*., 2011). Population growth and rising food demand continues to outpace productivity growth (Alobo, 2015; Badiane and Collins, 2016). Low inherent soil fertility and soil degradation through nutrient and organic matter depletion remain major constraints to food production and contribute to chronic poverty (Vanlauwe et al., 2015; Barrett and Bevis, 2015). Low and declining soil fertility has been recognized for a long time as a major impediment to intensifying agriculture in sub-Saharan Africa (SSA) (Vanlauwe et al., 2018). It has been projected that global food production must increase by 70 % by 2050 to meet the ever-increasing demand caused by burgeoning human population, increasing incomes and consumption (Ahmad et al., 2014). Several factors are contributing to high plant performance under different environmental conditions; therefore, an effective and complementary use of all the available technological tools and resources is needed to meet the challenge (Ahmad et al., 2014). Inorganic fertilizer and integrated use of inorganic and organic fertilizer are among the major alternative soil fertility management technologies used for yield improvement maize.

Currently, the skyrocketed prices of synthetic fertilizer have made it difficult for smallholder farmers to use inorganic nitrogen fertilizer for crop production. Furthermore, majority of smallholder farmers cannot afford mineral fertilizers, and those using fertilizer hardly use the recommended rates (Mugwe et al., 2009). Moreover, the little fertilizer available when added to the soil is often utilized with poor efficiency (Vanlauwe et al., 2010). Fertilizer use, especially the inorganic one is generally low in Africa as most farmers are satisfied with the fertility state of their soil (Sekumade, 2017). Also, Kherallah et al. (2002) gave some potential reasons for low fertility use rates as: high fertilizer cost, prevalence of traditional crop varieties that are less responsive to fertilizer and low incentives to invest in land-saving technologies. Furthermore, the crop takes up only a small fraction of this fertilizer (roughly 5% to 50%) (Carranca, 2012), but not all the nitrogen applied, since N could be lost by volatilization, gaseous plant emission, surface soil runoff, leaching and denitrification (Raun and Johnson, 1999). Of the total input in the form of nitrogen- and phosphorus fertilizers, only 15-20% is actually embedded in the food that reaches the consumers' plates, implying very large nutrient losses to the environment (Sutton et al.,2013), while in Sub-Saharan Africa soil nutrient depletion (where extraction is higher than the input) is common (FAO, 2015). Although essential for the maintenance of soil health, organic amendments such as manure, compost or crop residues are in short supply, suffer from competition for usage and are not able to compensate fully for nutrient losses from cropland (Valbuena et al., 2014). Organic amendments are often not available on farm at the amounts required (Getachew and Tilahun, 2017). The use of locally available manure is also limited by its low quality and quantity (Bationo and Waswa, 2011; Murwira et al., 2002; Sanginga and Woomer, 2009). Thus, indeed need of integrated use of inorganic and organic fertilizer for maize production in the area.

Integrating use of organic and mineral fertilizers is the best alternative technology used for tackling soil fertility depletion and sustainably increasing crop yields (Getachew and Tilahun 2017; Getachew et al. 2014; Gete et al. 2010). Integrated use of NP and farm yard manure (FYM) gave higher yield than application of either NP or FYM alone for maize production (Wakene et al., 2004a). Application of FYM every three years at the rate of 16 t ha^{-1} supplemented by NP fertilizer annually at the rate of 20-46 Kg N-P_2O_5 ha^{-1} was recommended for sustainable OPV maize production around Bako area (Tolessa, 1999). Likewise, the application of 4 tons FYM ha^{-1} incorporated with 75/60 kg of N/P ha^{-1} is economical and profitable combinations in boosting hybrid maize (BH-140) yield in west Hararghe zone, Eastern Ethiopia (Zelalem, 2014). Furthermore, integrated use of compost 5 t ha^{-1} with NP (Wakene et al., 2004b); full-recommended doses of NP with five ton per hectare crop residue (Heluf et *al*., 1999); and biogas slurry with NP fertilizer (Tolera et al., 2005) produced significantly higher grain yield of maize and improved soil physicochemical properties. Integrated use of green manure improved fallow with low doses of inorganic fertilizer or FYM gave higher mean grain yield of maize (Wakene et al., 2007); application of Sesbania sesban's biomass with dry FYM above five t ha^{-1} gave comparable or greater mean maize yield to 69 kg N ha^{-1} from urea fertilizer (Tesfa et al., 2012). The combined use of organic and inorganic inputs saves about 50% of the cost of inorganic nitrogen fertilizer on its own (Vanlauwe et al., 2001; Akinola et al., 2009) Therefore, integrated use of different organic fertilizers sources with inorganic fertilizer had improved maize grain yield and soil physiochemical properties. Integrated use of soil management technologies had reduced considerable amount of inorganic fertilizers and saved costs invested for chemical fertilizers in maize production (Tolera, 2016). Hence, there is a need to apply both organic and inorganic fertilizers in a balanced way to get expected output (Zebider, 2011). Different combinations of inorganic and organic fertilizer sources were therefore evaluated for soil fertility management in the different regions to suggest a viable and better alternative technology to current soil fertility management in maize production. However, no findings and researches studied the effects of integrated inorganic and organic fertilizer on yield of highland maize varieties in Ambo area. Therefore, optimum rate of integrated inorganic and organic fertilizer is the most important input for improving the production and productivity of maize. The objective is to determine effects of vermicompost and NPS fertilizer rate on yield and yield components of highland maize in Vertisol Ambo.

MATERIALS AND METHODS

Description of the study area

The experiment was conducted on smallholder farmers field around Ambo for three years from 2014 to 2016 cropping season. Geographically, it is located at 8°57''N latitude, 38°07''E longitude and at an altitude of 2185 meters above sea level. It receives a mean annual rainfall of 1100 mm. The minimum, maximum and mean temperatures of the area are 11, 26 and 18.5^{0}C, respectively. The soil type is Vertisol consisting of 67 % clay, 18 % silt and 15 % sand dominated by the clay fraction, with a pH of 7.5.

Experimental design, agronomic management practices and

This field experiment was laid out in a randomized complete block design with three replications. The plot size was 4.5 m x 5 m and with 25 cm and 75 cm between plants and rows. Maize varieties (Wenchi) was used. The treatments included eleven sole and integrated use of inorganic and vermicompost fertilizer rates. The treatments will include: (Zero input (control), recommended NPS vermicompost based on nitrogen equivalency (VBNE), 4 t/ha vermicompost, 6 t/ha vermicompost, 8 t/ha vermicompost, 10 t/ha vermicompost, 12 t/ha vermicompost 75% T3 + 25% RNPS, 50% T3 + 50% RNPS, 25% T3 + 75 % RNPS). Vermicompost, P and S were applied once at planting. Nitrogen from urea sources was applied two times half at knee height and half at tasseling maize. Hoeing and weeding were done as recommended for maize production in the area. The crop was harvested at its full maturity and shelled manually. Agronomic parameters such as height, dry biomass, thousand seed weight, harvest index and grain yield were collected at right stage the crop. The harvested grain yield was adjusted to 12.5 % moisture level (Biru, 1979 and Nelson et al., 1985). The adjusted seed yield at 12.5 % moisture level per plot was converted to grain yield as kilogram per hectare.

Statistical data analysis

The data analyses for agronomic data were carried out using statistical packages and procedures of SAS computer software (SAS, 2004). Mean separation was done using least significance difference (LSD) procedure at 5 % probability level (Steel and Torrie, 1980).

Economic analysis

Partial budget, value to cost ratio and marginal rate of return analysis, maize grain yield was valued at an average open market price of EB 650 per 100 kg. Labour cost for field operation was EB 28 per man-day. The yield was adjusted down by 10 % to reflect actual production conditions (CIMMYT, 1988). The cost of fertilizer (NPS, Urea and DAP) were EB 1400, 1090 and 1390 per 100 kg with current market price. Vermicompost price= 250 EB t^{-1}.

RESULTS AND DISCUSSION

Thousand seed weight and plant height of high land of maize

The mean thousand seed weight and plant height of high land of maize are indicated in Table 1. The mean thousand seed weight of highland maize was significantly ($P<0.05$) affected by application sole and integrated use of NPS fertilizer and vermicompost combined over years (Table 1). Significantly higher mean thousand weight of highland maize was obtained from application NPS followed by integrated use of NPS with Vermicompost and higher rate of vermicompost (Table 1). This indicates the easily release of nutrients from NPS fertilizer followed by integrated use of NPS and vermicompost and gradually release from higher rate of vermicompost which available for maize growth. Likewise, Abdissa et al. (2018) found interaction effect of lime, VC and mineral P fertilizer had highly significant effect on 1000-seed weight of maize with higher mean 1000-seed weight (508 g) was obtained with application of 2.5 t VC ha^{-1}and 40 kg P ha^{-1} and lime, while the lowest (255 g) was in the control which might be due to the synergistic effects of the combined effects of VC and lime in improving growth and grain filling of maize, the physicochemical and biological soil properties

Similarly, Mohsin et al. (2012) found application of 50% N from manure along with 50% N from mineral fertilizers produced maximum 1000-grain weight (279g). Likewise, Tesfaye (2017) reported combined application of compost and mineral fertilizers significantly affect ed thousand seed weight of maize. Significantly higher thousand seed weight (269 g) was recorded with combined application of 100 % NPK + vermicompost at 3 t ha^{-1} followed by 100% NPK + FYM at 3 t ha^{-1} (Shah and Wani, 2017). Application of vermicompost and chemical nitrogen fertilizer affects the 1000 seed weight of maize (Namazi et al., 2015). Athokpam et al. (2017) found higher 1000 grain weight (198 g) was produced under the application of 100 % NPK + Vermicompost 5 t ha^{-1}

The mean plant height of highland maize was significantly (P<0.05) affected by application of sole NPS, vermicompost and integrated use of NPS and vermicompost from 2015 to 2017 cropping seasons and combined over years in Vertisol of Ambo.

Table 1. Effects of NPS fertilizer and vermicompost rate on thousand seed weight and plant height, of high land of maize from 2015 to 2017 cropping season in Vertisol of Ambo

NPS and Vermicompost (kg and t ha^{-1})	Thousand seed weight (g)				Plant height (cm)			
	2015	2016	2017	Mean	2015	2016	2017	Mean
0	344	313	372	343b	208c	196de	197de	200e
92/69/30 kg NPS	337	476	342	385a	228ab	249a	250a	242a
VBNE (92 kg N)	315	428	338	360ab	231a	221bcd	222bcd	224bc
4 t vermicompost	330	318	343	330b	228ab	196de	197de	207de
6 t vermicompost	340	347	343	343ab	222abc	197de	198de	205de
8 t vermicompost	316	392	335	348ab	214bc	220bcde	221bcd	218cd
10 t vermicompost	307	404	365	359ab	235a	208cde	209cde	217cd
12 t vermicompost	299	357	349	335b	235a	216cde	217cd	222bc
75 % T3 + 50%RNPS	342	418	354	371ab	232a	233abc	234abc	233ab
50 % T3 + 50%RNPS	308	400	370	359ab	226ab	247a	248a	240a
25 % T3 + 75%RNPS	320	348	363	344ab	236a	244ab	245ab	241a
LSD (5%)	NS	NS	NS	42	17.05	25.148	25.185	12.536
CV (%)	14.4	9.2	8.83	12.65	6.7	4.42	6.70	5.98

NS= non-significant difference at 5 % probability level, Numbers followed by same letter in the same column are not significantly different at 5 % probability level, VBNE=vermicompost based on N equivalency, R = recommended NPS.

Significantly higher mean plant height of highland maize was obtained from application of NPS followed by integrated use of NPS with Vermicompost and higher rate of vermicompost but the lower plant height highland of maize was obtained from non-fertilized maize fields. Likewise, Yadav et al. (2016) reported significantly higher (213cm) of maize was obtained from application of 5 t ha^{-1} vermicompost +75% recommended dose of N.P.K as compared to control (193cm). Better performance of highland maize was obtained from easily and higher release of nutrients from applied fertilizer sources and rates. Similar result was reported by Habtamu et al. (2015) with integration of compost, nitrogen and Sulfur on maize; Adekayode and Ogunkoya (2010) reported significant difference in maize plant height with high fertilizer treated as compared to nil applied plots. Likewise, Rehman et al. (2016) reported plant height was increased with the addition of farm manure over the control. Significantly higher plant height of maize with increasing rate of compost and mineral fertilizer rate could be due to their synergistic effects compost and mineral fertilizer (Tesfaye 2017). Likewise, Yadav et al. (2017) reported significant effects integrated nutrient management on plant height of maize.

Harvest index and stalk biomass of high land of maize

The mean harvest index and stalk biomass of highland of maize are indicated in Table 2. The mean harvest index of highland of maize was significantly (P<0.05) affected by sole and integrated by application of NPS, vermicompost and integrated use of NPS with vermicompost in 2016, 2017 cropping seasons and combined over years in Vertisols of Ambo (Table 2). Significantly higher mean harvest index of highland of maize was obtained from application of NPS followed by integrated use of NPS with Vermicompost and higher rate of vermicompost but the lower harvest index of highland of maize was obtained from non-fertilized maize fields indicating better harvest index with higher release of available nutrients for highland maize. Similarly, harvest index of maize was significantly affected by integrated use of compost and NPSBZn chemical fertilizer (Tesfaye 2017). Likewise, Abdissa et al. (2018) found significantly higher mean harvest index of (24.4%) was obtained from application of 2.5 t VC ha^{-1} and 40 kg P ha^{-1} with lime, while the lowest (13.4%) was observed when only lime was applied without VC and mineral P fertilizer In India, Yadav et al. (2016) found significantly higher mean biological yield of (43.51%) maize was obtained from application of 5 t ha^{-1} vermicompost +75% recommended dose of N.P.K as compared control (31.37%). Likewise, Syed *et al*. (2009) reported that harvest index was significantly affected by the organic and inorganic source of N. Dzomeku and Illiasu (2018) reported similar result on integration of organic material and NPK fertilizer. Application of vermicompost and chemical nitrogen fertilizer has positive and meaningful effect on the harvest index of maize (Namazi et al., 2015).

The mean stalk biomass of maize was significantly ($P<0.05$) affected by sole and integrated application of NPS and vermicompost in 2015 and 2017 cropping seasons (Table 2). Significantly higher mean stalk biomass of 12467 kg ha^{-1} followed by 11898 kg ha^{-1} was obtained from application of sole NPS and 50:50 recommended NPS with vermicompost based on N equivalency (Table 2).

Table 2. Effects of NPS fertilizer and vermicompost rate on harvest index and stalk biomass of highland of maize from 2015 to 2017 cropping season in Vertisol of Ambo

NPS and Vermicompost (kg and t ha^{-1})	Harvest index (%)				Stalk biomass (kg ha^{-1})			
	2015	2016	2017	Mean	2015	2016	2017	Mean
0	37.64	27c	33ab	33b	9999c	76023	6310c	30777
92/69/30 kg NPS	37.00	57a	33ab	42a	12375ab	94653	12467a	39832
VBNE (92 kg N)	35.77	43abc	31ab	37ab	12236ab	74585	7018c	31280
4 t vermicompost	37.08	31bc	27b	32b	10722d	74762	8500bc	31328
6 t vermicompost	34.52	31bc	38a	35b	10833d	75083	6000c	30638
8 t vermicompost	35.20	48ab	31ab	38ab	11773cd	68509	7181c	29154
10 t vermicompost	37.30	34bc	30ab	34b	11434bc	71525	7983c	30314
12 t vermicompost	35.24	38bc	29ab	34b	12453a	79304	8116c	33291
75 % T3 + 50%RNPS	36.85	38bc	31ab	35b	12596a	87522	7711c	35943
50 % T3 + 50%RNPS	35.78	42abc	31ab	36b	10939ab	96809	11898ab	39882
25 % T3 + 75%RNPS	38.27	45ab	30ab	38ab	12089	90880	8392bc	37120
LSD (5%)	NS	16.857	9.48	6.71	2115	NS	3545	NS
CV (%)	25	7.07	17.87	19.93	10.72	24.21	25	24.35

NS= non-significant difference at 5 % probability level, Numbers followed by same letter in the same column are not significantly different at 5 % probability level, VBNE=vermicompost based on N equivalency, R = recommended NPS.

Similarly, Tesfaye (2017) stover yield of maize was significantly affected by interaction of compost and inorganic fertilizer, with higher stover yield of (8.54 t ha^{-1}) was observed when 10 t ha^{-1} compost was applied with combination of full recommended dose of mineral fertilizer. The easily and timely release of available nutrients had contributed for better stalk biomass performance of highland maize in Vertisols of Ambo.

Mean grain yield of highland of maize

The mean grain yield of highland maize is indicated in Table 3. The mean grain yield of highland maize was significantly ($P<0.05$) affected by application of NPS, vermicompost, integrated use of NPS and vermicompost rate in 2015, 2016, 2017 and combined over years in Vertisols of Ambo (Table 3). Significantly lower mean grain yield of maize was obtained from non-fertilized plots as compared fertilized plots. Significantly higher combined mean grain yield of highland maize of 6187kg ha^{-1} followed 5193,5083 and 4746 kg ha^{-1} was obtained from sole application of NPS and integrated use of NPS with vermicompost rate (Table 3).

Table 3. Effects of NPS fertilizer and vermicompost rate on grain yield of highland of maize from 2015 to 2017 cropping season in Vertisol of Ambo

NPS and Vermicompost (kg and t ha^{-1})	Grain yield (kg ha^{-1})			
	2015	2016	2017	Mean
0	5999bc	1938f	2911c	3616e
92/69/30 kg NPS	7274ab	5112a	6176a	6187a
VBNE (92 kg N)	6813abc	3219cde	3124c	4385cde
4 t vermicompost	6326abc	2414ef	3162c	3967de
6 t vermicompost	5761c	2407ef	3846bc	4005de
8 t vermicompost	6351abc	3334cd	3163c	4283de
10 t vermicompost	6777abc	2514def	3472c	4254de
12 t vermicompost	6784abc	3049cde	3286c	4373de
75 % T3 + 50R NPS	7357ab	3459bc	3421c	4746bcd
50 % T3 + 50 RNPS	6092abc	4210b	5278ab	5193b
25 % T3 + 75RNPS	7480a	4179b	3590c	5083bc
LSD (5%)	1462	836.13	1642	799
CV (%)	15.1	12.9	25.61	18.64

Numbers followed by same letter in the same column are not significantly different at 5 % probability level, VBNE=vermicompost based on N equivalency, R = recommended NPS.

This indicates the faster release of available nutrients from NPS fertilizer had significant contribution for better grain yield of maize as compared to the slow gradually release of nutrients from vermicompost. Sole application of vermicompost gave similar yield with different rates across years (Table 3). Application of 50: 50 % vermicompost based on N equivalency with recommended NPS fertilizer rate gave better grain yield of maize following recommended NPS fertilizer indicating greater contribution of vermicompost in nutrient release for maize and reducing the amount of NPS fertilizer for maize production. Similarly, Yadav et al. (2016) found significantly higher mean grain yield of (4.77 t ha^{-1}) was obtained from application of 5 t ha^{-1} vermicompost +75%

recommended dose of N.P.K in India. It saved the cost chemical fertilizer for maize production. Integrated use of organic and mineral fertilizers resulted in yield, environmental and economic benefits as compared to using alone. Likewise, Abdissa et al. (2018) combined use of vermicompost at 2.5 t ha^{-1} and chemical P fertilizer at 20 kg ha^{-1} with lime at 4 t ha^{-1} was produced significantly higher mean grain yield (4.87 t ha^{-1}) was obtained with application of 40 kg P ha^{-1} and 2.5 t VC ha^{-1} with lime, while the lowest (2.18 t ha^{-1}) was from control in strongly acidic soils. Tilahun et al. (2013) also verified that integrated fertilizers application gave the maximum grain yield compared to the control. Similar results were reported by Wakene et al. (2005); Habatmu et al. (2015); Mahmood et al. (2017). Several studies Liu et al. (2009); Yu et al., (2012); Cavagnaro (2014); Xie et al. (2014); Molina-Herrera and Romanya (2015); Srivastava et al. (2015, 2016); Wang et al. (2015); Ling et al. (2016) reported that organic amendments have improved soil physical, chemical, and biological properties, providing essential plant nutrients to stimulate plant growth and yield. Combined organic and inorganic fertilizers increased significantly the expected and obtained yields for maize and soybean intercropping (Muyayabantu et al., 2013). Likewise, Rodriguez- Vila et al. (2016) found that organic amendments sustain soil properties by increasing OM, nutrient content, microbial activity and thus increase crop growth and yield. Similarly, Mohsin et al. (2012) found application of 50% N from manure along with 50% N from mineral fertilizers produced higher grain yield (5793 kg ha^{-1}). Higher maize grain yield was obtained from the application of 10 tons ha^{-1} compost and full recommended mineral fertilizer rate 150 kg NPSBZn ha^{-1} + 200 kg 100 % NPK + S + Zn and 150 % NPK (Athokpam et al.,2017). The higher grain yield of maize in integrated use of vermicompost and NPS fertilizer might be due to better nutrient use efficiency of maize which is in agreement with Matsui et al. (2016) found nitrogen use efficiency (NUE) was greatly improved 2 to 5 times larger when chemical fertilizer (46 kg N) was Urea ha^{-1} (Tesfaye, 2017). He further stated that grain yield of maize was increased by 81% due to the combined application of compost and mineral fertilizer over the control. Likewise, Taffesse *et al*. (2011) reported applying FYM at 15 t ha^{-1} with 120/20 kg NP ha^{-1} responded the maximum grain yield which increased by 123 % compared to the control. Mugwe *et al*. (2007) also reported higher maize yields in treatments of compost either alone or in combination with mineral fertilizer were applied compared to the control. Maximum grain yield of (3.26 t ha^{-1}) was recorded with combined application of 100 % NPK + vermicompost at 3 t ha^{-1} followed by 100% NPK + FYM at 3 t ha^{-1} (Shah and Wani, 2017). Correspondingly, N'Dayegamiye *et al*. (2010) who reported that application of compost with 120 kg N ha^{-1} led to high maize yields. Significantly higher seed yield of maize was obtained from application 5 t ha^{-1} vermicompost together with 75% nitrogen while the lowest from combination of 10 t ha^{-1} vermicompost and 50 % nitrogen fertilizer (Namazi et al., 2015). Similar finding was reported by Sadeghi and Bahrani (2009).

Combined application of both organic and inorganic sources to take care of maize nutrition more effectively leading to better productivity (Yadav et al., 2016). Integration of organic material and NPK fertilizer significantly increased mean grain yield maize with higher grain yield of maize (4781 kg ha^{-1}) at 7.5 t ha^{-1} groundnut shell plus 90-60-60 kg NPK ha^{-1} (Dzomeku and Illiasu, 2018). Higher maize grain yield was obtained in treatment having NPK with FYM Babbu et al. (2015). Yadav et al. (2017) also reported similar result. Higher grain yield (38 q ha^{-1}) was produced by application of 100 % NPK + Vermicompost 5 t ha^{-1} and its performance was at par with applied mixed with compost which have direct influence on yield of maize. Sanginga and Woomer (2009); Vanlauwe et al. (2010) reported integrated Soil Fertility Management (ISFM) options for increasing soil fertility and agronomic efficiency of applied inputs. Vermicompost integrated with inorganic fertilizers were efficiently used by maize crop for their growth and development and also maintained soil fertility and increased yield of the crop (Sanjivkumar, 2014). Athokpam et al. (2017) found higher available nitrogen (499 kg ha^{-1}), phosphorus (34.08 kg ha^{-1}) was obtained from plots receiving 100 % NPK + Vermicompost 5 t ha^{-1}, while maximum potassium (338 kg ha^{-1}) from treatment receiving 150 % NPK. Similar results in respect of N, P and K status of soil also reported by Tetarwal *et al*., (2011). Shah and Wani (2017) reported integrated nutrient management strategy revealed that application of full dose of inorganic fertilizers along with vermicompost at 3 t ha^{-1} to maize not only enhanced productivity of maize by 90% and 13.4% over the control and Recommended NPK, respectively, but also improved soil fertility in terms of higher available N, P and organic carbon.

Mean dry biomass yield of high land of maize

The mean dry biomass yield of highland maize is indicated in Table 4. The mean biomass yield of highland maize was significantly (P<0.05) affected by application of sole NPS, vermicompost and integrated use of vermicompost with NPS in 2015, 2017 cropping seasons and combined over years

Table 4. Effects of NPS fertilizer and vermicompost rate on biomass yield of highland of maize from 2015 to 2017 cropping season in Vertisol of Ambo

NPS and Vermicompost (kg and t ha^{-1})	Dry Biomass (kg ha^{-1})			
	2015	2016	2017	Mean
0	15998c	77961	9221b	34393bc
92/69/30 kg NPS	19649ab	99765	18643a	46019a
VBNE (92 kg N)	19049abc	77804	10142b	35665abc
4 t vermicompost	17049abc	78176	11662b	35296abc
6 t vermicompost	16593bc	77490	9846b	34643bc
8 t vermicompost	18124abc	71843	10344b	33437c
10 t vermicompost	16211abc	74039	11455b	34568bc
12 t vermicompost	19238ab	82353	11401b	37664abc
75 % T3 + 50 R NPS	19953a	90980	11132b	40688abc
50 % T3 + 50 RNPS	17031abc	101020	17176a	45076ab
25 % T3 + 75 R NPS	19569ab	95059	11982b	42203abc
LSD (5%)	3197	NS	4731	11088
CV (%)	23.57	10.3	22.97	20.86

NS= non-significant difference at 5 % probability level, Numbers followed by same letter in the same column is not significantly different at 5 % probability level, VBNE=vermicompost based on N equivalency, R = recommended NPS.

Significantly higher biomass yield of highland maize of 46019 kg ha^{-1} was obtained from sole application of NPS fertilizer followed by integrated use of NPS with vermicompost fertilizer rates combined over years as compared other rates (Table 4). This indicates easier release of nutrients from inorganic NPS fertilizer and combination of NPS with vermicompost could enhance the biomass yield of highland maize as compared to gradually release of nutrients from sole vermicompost rates. Similarly, Mohsin et al. (2012) found application of 50% N from manure along with 50% N from mineral fertilizers produced maximum biological yield (14880 kg ha^{-1}). Significantly higher mean biomass yield of (12.78 t ha^{-1}) maize was recorded with the application of higher rates of vermicompost and mineral P along with lime, while the minimum (5.02 t ha^{-1}) from control with a difference of 7.16 t ha^{-1} (Abdissa et al., 2018). Significantly higher (14.9 t ha^{-1}) dry biomass of maize was recorded in plots treated with 10 t ha^{-1} compost and full recommendation of mineral fertilizer, while the lowest (2.16 t ha^{-1}) in the control with a difference of 12.74 t ha^{-1} (Tesfaye, 2017). Kibunja *et al*. (2010) reported that total dry matter of maize was higher in treatment combinations of inorganic and organic fertilizers than chemical fertilizers alone. Similarly, Yadav et al. (2016) found significantly higher mean biological yield of (10.56 t ha^{-1}) maize was obtained from application of 5 t ha^{-1} vermicompost +75% recommended dose of N.P.K as compared control (7.76 t ha^{-1}) in India. Application 5 t ha^{-1} vermicompost together with 75% nitrogen gave significantly higher biological yield of maize (12,566 kg ha^{-1}) while the lowest (9890 kg ha-

1) was from combination of 10 t ha-1 vermicompost and 50 % nitrogen fertilizer (Namazi et al., 2015). Similar result was reported by (Dzomeku and Illiasu, 2018; Yadav et al., 2017). Integrated use of vermicompost and NPS fertilizer significantly improved biomass yield of maize. Likewise, Dzomeku and Illiasu (2018) stated combination of organic matter and inorganic NPK fertilizer could play a more significant role in enhancing and replenishing soil nutrients and sustained maize production.

Integrated use of NPS fertilizer and Vermicompost on economic profitability of highland maize production

Application of 92/69/30 kg NPS ha^{-1} gave the highest net return of EB 32265 with highest marginal rate return of 713 % with values to cost ratio of EB 8.21 profit per unit investment for maize production in vertisols of Ambo followed by net return of EB 27167 and marginal rate return of 295 % with values to cost ratio of EB 8.45 profit per unit investment for highland maize production was obtained from application of 50:50 % recommended NPS with vermicompost based on N equivalency (Table 5).

Table 5. Effects of NPS fertilizer and vermicompost rate on economic profitability of highland of maize production at Ambo

Treatments (t VC and kg NPS ha^{-1})	Items						
	Grain yield (kg ha^{-1})	Adjusted Grain yield (kg ha^{-1})	Gross field benefit (EB ha^{-1})	TVC (EB ha^{-1})	Net benefit (EB ha^{-1})	Value to cost ratio	MRR (%)
0	3616	3254	21153	0	21153		
4 t vermicompost	3968	3571	23211	1000	22211	22.21	106
6 t vermicompost	4005	3604	23428	1250	22178D	17.74	
8 t vermicompost	4283	3854	25054	1500	23554	15.70	268
10 t vermicompost	4254	3829	24887	1750	23137D	13.22	
12 t vermicompost	4373	3936	25583	2000	23583	11.79	6
VBNE (92 kg N)	4385	3947	25654	2500	23154D	9.26	
50 % T3 + 50 %R NPS	5193	4674	30382	3215	27167	8.45	295
25 % T3 + 75% R NPS	5083	4575	29736	3573	26163D	7.32	
75 % T3 + 50 % R NPS	4746	4271	27762	3840	23922D	6.23	
92/69/30 kg NPS	6187	5568	36195	3930	32265	8.21	713

D= dominated, TVC= Total variable cost, MRR= Marginal rate of return, maize grain price = 6.5 EB kg^{-1}, NPS=14 EB kg^{-1}, DAP= 13.9 EB kg^{-1}, Urea price= 10.90 EB kg^{-1}, Vermicompost price= 250 EB t^{-1}, Labour cost= 28 EB day^{-1}, VBNE=vermicompost based on N equivalency, R = recommended NPS

Similarly, Tesfaye (2017) application of 10 t ha^{-1} compost and full of the recommended mineral fertilizer rate (150 kg NPSBZn ha^{-1} and 200 kg ha^{-1} urea) was found to be economical feasible for maize production. Significantly higher net return was obtained in 5 t ha^{-1} vermicompost +75% recommended dose of N.P.K (Yadav et al., 2016). Combined use of vermicompost at 2.5 t ha^{-1} and chemical P fertilizer at 20 kg ha^{-1} with lime at 4 t ha^{-1} is economically optimum for maize production in acid soil (Abdissa et al., 2018). Therefore, application of recommended NPS or 50:50 % recommended NPS with vermicompost based on N equivalency was recommended for better maize production and economic return in Vertisols of Ambo District, west Showa.

CONCLUSION

Application of sole and integrated use of vermicompost and NPS fertilizer rate were significantly affected yield and yield components of highland maize variety. Significantly higher (6187 kg ha^{-1}) was obtained with application of 92/69/30 kg NPS ha^{-1} followed by (5193 kg ha^{-1}) with 50:50 vermicompost based on N equivalency and NPS fertilizer rate. Application of 92/69/30 kg NPS ha^{-1} gave the highest net return of EB 32265 with highest marginal rate return of 713 % followed by net return of EB 27167 and marginal rate return of 295 % for highland maize production was obtained from application of 50:50 % recommended NPS with vermicompost based on N equivalency in Vertisols of Ambo. Thus application of 92/69/30 kg NPS ha^{-1} and 50:50 % recommended NPS with vermicompost based on N equivalency produced better grain yield and economical feasible for maize production Therefore, application of 92/69/30 kg NPS ha^{-1} and 50:50 % recommended NPS with vermicompost based on N equivalency were recommended for highland maize production in Vertisol of Ambo and similar agro-ecologies in western Oromia.

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