Vermicompost Rate Determination for Bread Wheat (*Triticum aestivum* L.*)* in Yilmanadensa district, West Amhara, Ethiopia

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Abstract

A field experiment was carried out at Adet Agricultural Research Center to determine the effect of vermicompost in relation to the NP fertilizer on grain yield of wheat (Triticum aestivum) and chemical properties of soil at Adet experimental station in Western Amhara, Ethiopia. The treatments include a combination of 0, 3, 6, 9, and 12 ton vermicompost in factorial combination with 0 + 0, 46 kg N + 23 kg P_2O_5 and 92 kg N + 46 kg P_2O_5 ha^{-1}. The experiment was laid in a randomized complete block design with three replications. The higher (4125.6 kg ha^{-1}) grain yield and net benefit (62459.15 ETB ha^{-1}) were obtained with the combination of 9 ton vermicompost with 46N+23P_2O_5 kg ha^{-1}. The highest marginal rate of return (373.62%) with a net benefits of 48994.17 ETBha-1 was obtained from the combination of 3ton vermicompost with 92 N+46P_2O_5kg /ha. Soil chemical properties like soil pH, Total Nitrogen, Organic matter and availability of phosphorus improve from the initial.

Keywords: *Available Phosphorous, Biomass, Grain yield, Soil pH, Total nitrogen*

Introduction

Wheat (*Triticum aestivum* L.*)* is one of the main cereals cultivated in Ethiopia as it provides 14 percent of the total caloric intake, ranking as the second most important food behind maize (FAO, 2019). Wheat is used to prepare traditional food and beverages such as Dabbo (homemade bread), Enjera and Nifro, Tela, etc. It is also being used by food processing industries to prepare local bread, biscuits, pasta and macaroni. Although the production is dominated by smallholder farmers and almost the entirety of wheat is produced under rain-fed conditions, Ethiopia is the largest wheat producer in Sub-Saharan Africa. In Ethiopia, 4.8 million farmers are engaged in wheat production, namely about 32 percent of total farmers of grain cultivation (FAO, 2019).

Despite, large area of land cultivated and suitable climate for wheat production in Ethiopia, the country is unable to produce sufficient amount of wheat grain to meet its annual domestic need. The Central Statistical Agency (2019.) reported that out of the total cereal crop area, 81.39% wheat took up 13.78% about 1,747,939.31 ha of area coverage with annual average yield of 27.64 quintal.

Thus, decline in soil fertility among others is the main cause of low productivity of wheat in the country. Application of inorganic fertilizer especially those containing N and P have long been practiced to improve soil fertility for enhanced wheat and other crop production as these nutrients are the most limiting nutrients in almost all Ethiopian soils (ATA, 2014). However, fertilizers were applied irrespective of soil and crop types as well as agroecology. Such kind of blanket application of fertilizers are unrealistic due to the fact that the amount and type of fertilizer that should be applied can widely vary based on soil and crop type, and agroecology. Inorganic fertilizers are considered to be an important source of major elements in crop production. Always use of inorganic fertilizer resulted in a deficiency of micronutrients, imbalance in soil physicochemical properties and unsustainable crop production (Jeyathilake et al., 2006). To ensure soil productivity, plants must have an efficient and balanced supply of nutrients that can be realized through integrated nutrient management where both natural and synthetic sources of plant nutrients are used (Gruhn et al., 2000). Vermicompost is produced through the processing of organic matter by a large variety of earthworm genera, but commonly with *Eisenia fetida*

1988, Mitchell, 1997). It can be produced from a variety of organic material from different sources, farm wastes (Azarmi et al., 2008), animal wastes (Atiyeh et al, 2001) garden wastes, sewage sludge from municipal wastewater and water treatment plants (Sinha et al., 2009), Vermicomposting technology using earthworms (as versatile natural bioreactors for effective recycling of organic wastes to the soil) is an environmentally acceptable means of converting waste into nutritious composts for crop production (Edward *et al*., 1985). Organic fertilizer can serve as a source of SOM and source of nutrients needed for the growth and production of crops. However, it is difficult to have sufficient amount of vermicompost that can supply adequate amount of nutrients needed by crops in smallholder

important to ensure adequate and balanced supply of nutrient to crops. With integrated nutrient management approach, the inorganic fertilizer can supplement with readily available nutrients to plants at early stages whereas organic fertilizers at later growth stages of plant that can boost yield and reduce the associated risks of chemical fertilizers (Mitiku et al., 2014). Integrated application of inorganic and organic fertilizers increases fertilizer use efficiencies, ensure balanced nutrient supply to crops, improve soil sustainability, etc. There are several authors indicating the multiple advantages with combined application of organic and inorganic nutrient sources over that obtained with sole application of either source (Sangiga and Woomer, 2009; Singh et al., 2011;Kumar et al., 2015;). Therefore, the objectives of this experiment was to determine the residual effects of integrated applications of vermicompost and NP fertilizers on the yield and yield components of bread wheat.

Materials and Methods

Description of Study Area: The study was conducted for three consecutive years during 2017 to 2019 GC main cropping seasons at Adet agricultural research center main station in

on an altitude of 2240 m above sea leve. The center receives average annual rainfall of 1250 mm and the average temperature is 18°C.

Experimental Setup: The treatments consisted of factorial combinations of five levels (0, 3, 6, 9 and 12 ton ha^{-1}) of vermicompost (VC) and three levels (0, 50% (N46 $kg^{-1}$and $P_2O_5$23 kg^{-1}) and 100% (N92 $kg^{-1}$and $P_2O_5$46 kg^{-1}) of recommended fertilizers. The experiment was laid out in RCB design with three replications. Vermicompost was processed by earthworm *(Eisinea fetida)* using cow manure, fababean, maize and wheat straw as main feedstock. Urea and TSP, were used as nitrogen (N), phosphorus (P) sources. Gross plot size was 3 × 3 cm and net plot size was 2.6 ×3 cm. The spacing between plots was 1 meter and between block was 1.5 meter. Then seed of wheat variety, Tay was planted on row as a test crop. The spacing between rows was 20cm. The entire dose of phosphorous was applied at planting, while N was applied in split, half at sowing and the remaining half side dressed at tillering stage of wheat. The experimental plots were kept permanent to observe the residual effects of vermicompost over years.

Soil Sampling and Analysis: Prior to planting and before application of vermicompost composite soil samples were taken from the experimental site using soil auger from the depth of 0-20 cm. At harvesting, soil samples from each treatment were taken and independently analyzed. Soil samples were air dried under shade, grounded by mortar & pestle, and sieved to pass through 2 mm mesh.

Soil and Vermicompost Analysis: The pH was determined using glass electrode pH meter in 1:2.5 soils to water ratio. Available phosphorous was determined by Olsen (Olsen & Sommer, 1982) method. Organic carbon (OC) was determined following the Walkley and Black wet digestion method (Van Reeuwijk, 1992). Total nitrogen was analysed by Kjeldahl method (Bremner and Mulvaney, 1982).

Table 1. Some initial chemical properties of the soil and vermicompost used in experiment.

Parameter	Sample source	
	Soil	Vermicompost (VC)
pH	5.85	7.8
Av P (ppm)	4.10	12.69
Total N (%)	0.13	0.97
OC (%)	1.42	10.19
C/N	10.92	10.50

Agronomic Data Collection and Interpretation: Data on soil, dry biomass, and grain yield were subjected to analysis of variance (ANOVA) using SAS software version 9.0 (SAS, 2002). Mean were separated using least significance difference (LSD) method at 0.05 probability level.

Economic Analysis of Treatment: Partial budget analysis of treatments was done according to CIMMYT (1988). The mean grain yield data of wheat which were produced by each treatment over three experimental years (2017 and 2019) were used to do the partial budget analysis. The mean grain and straw yield data were also further adjusted down by 10% to minimize the yield gap that may occur due to plot management difference by researchers and farmers (CIMMYT, 1988).

The average prices of relevant data which were needed to do the partial budget analysis were collected from different sources. Thus, the field price of 1 kg of wheat in 2020 at local market was 14.5 Ethiopian Birr (ETB) and was taken as a field price of wheat. The current price of Urea was 12.5 ETB kg-^{1}, and TSP 14.5 ETB kg-^{1}. The price of phosphorous source fertilizers (TSP) was calculated by the current price NPSZn fertilizer.

Results and Discussion

Grain Yield and Aboveground Biomass: Main effects of vermicompost with NP fertilizers on biomass and wheat grain yield of all year data are presented in Table 2. All vermicompost rates produced significantly above ground biomass and grain yield of wheat than the control. But the highest values of these parameters were obtained with 9 ton followed by 3 ton VC in that order. This is in agreement with findings of Joshi et al., (2013) who reported that application of vermicopost to soil significantly increases the yield of wheat. Besides, different studies have also illustrated the beneficial effect of vermicompost application at different rates on the yields of other crops such (Kashem et al., 2015), maize and barley (Mitiku et al., 2014). As vermicopost is a source of different plant nutrients, its application in soil with low nutrient content will definitely increase the growth, yield and yield components of crops including wheat. However, in addition to being sources of various nutrients, vermicompost is also supposed to have growth promoting hormones (Edwards et al., 2004) which might facilitate higher nutrient uptake by plants and this could be an addition factor for the positive impact of vermicompost on crops. Similarly, all NP fertilizers rates produced significantly higher above ground biomass and grain yield of wheat than the control (Table 2). 92N and 46 $P_2o_5^{-1}$(100%) produced the highest yield than that produced by all other fertilizer treatments and it increased the biomass and grain yield by 63.6% and 48.4% over the control, respectively.

Table2. Main effects of vermicompost and NP on biomass and grain yield.

Treatment	**2017**		**2018**		**2019**		**Combined**	
NP (kgha^{-1})	**BM kgha^{-1}**	**GY kgha^{-1}**	**BM kgha^{-1}**	**GY kgha^{-1}**	**BM kgha^{-1}**	**GY kgha^{-1}**	**BM kgha^{-1}**	**GY kgha^{-1}**
0 NP	3836.1	2278.2	3191.7	1344.7	2785.5	1259.1	3271.1	1643.3
46 N + 23 P_2O_5 (50%)	4929.5	2872.2	4874.1	3275.4	4389.5	3187	4731	3111.5
92 N + 46 P_2O_5 (100%)	5230.9	3513.2	5739.7	3540.1	4436.5	3114.7	5135.7	3389.3
LSD 5%	709.09	397.94	836.5	233.2	606.6	370.4	441.2	227.5
VM (tha^{-1})								
0	2894.8	1893.9	3092.9	2057.2	3783.8	2203.9	3257.1	2078.3
3	4510.1	2668.4	4853.4	2663.3	3336	2512.3	4233.2	2614.7
6	5074.4	3267.6	5053.2	2970.9	3961.3	2514.6	4696.3	2917.7
9	6000.1	3559.2	5761	3219.9	4199.8	2860.9	5320.3	3213.3
12	4848	3050.2	4248.6	2688.9	4071.7	2509.7	4389.4	2749.6
LSD 5%	**915.4**	**513.7**	**1079.9**	**301**	**NS**	**NS**	**569.6**	**293.7**
NP*VC	**	**	**NS**	**NS**	**NS**	**	**NS**	**NS**
CV %	**20.6**	**18.6**	**24.6**	**11.6**	**21.2**	**19.9**	**24.1**	**20.1**

** (highly significant at $p<0.01$)

The positive effects of vermicompost and NP fertilizers application on wheat seen in this experiment suggest that the study soils are low in its nutrient contents particularly of NP this showed on the result of initial soils analyses data (Table 1). Vermicompost by NP fertilizer interaction effect was highly significant ($P<0.001$) for biomass and grain yield of wheat during the first year (Table 2). Accordingly, the highest biomass and grain yield was produced by treatment involving 9ton with 46N and 23 $P_2o_5^{-1}$. This produced significantly higher biomass and grain yield of wheat than that produced by sole application of vermicompost and NP fertilizers. The result suggests that there was a synergistic interaction between the two nutrient sources in availing nutrients to the growing wheat and the research is in agreement with report of Davari et al (2012). In line with the current finding, Seal et al. (2014) reported that biomass and grain yield, is also significantly increased by the combined application of vermicompost and NP fertilizers.

Table3. Interaction effects of vermicompost and NP fertilizers on Biomass and Grain yield of Wheat

Treatment	**BM kgha^{-1}**	**GY kgha^{-1}**
0 tVM + 0N, 0P_2O_5 (0%NP)	1489.9	648.9
0 tVM + 46N,23 0P_2O_5 (50% NP)	3258.3	2088
0 tVM + 92N,46 0P_2O_5 (100% NP)	4689.9	3475.9
3 tVM + 0N, 0P_2O_5 (0%NP)	2960.3	1587
3 tVM + 46N, 23P_2O_5 (50% NP)	4531.6	2885
3 tVM + 92N,46 P_2O_5 (100% NP)	5207.7	3372.1
6 tVM + 0N, 0P_2O_5 (0%NP)	4859.3	1896.8
6 tVM + 46N,23 P_2O_5 (50% NP)	4228.7	3291.9
6 tVM + 92N,46 P_2O_5 (100% NP)	5001	3564.3
9 tVM + 0N, P_2O_5 (0%NP)	3480	2174.9
9 tVM + 46N,23 P_2O_5 (50% NP)	6859.8	4125.6
9 tVM + 92N,46 P_2O_5(100% NP)	5621.1	3339.6
12 tVM + 0N, P_2O_5 (0%NP)	3232.8	1886.9
12 tVM + 46N,23 P_2O_5 (50% NP)	4776.8	3167.2
12 tVM + 92N,46 P_2O_5 (100% NP)	5158.7	3194.7
CV %	18.7261	16.651
LSD 5%	761.66	421.73

Chemical Properties of Compost: The organic carbon and total nitrogen contents of the compost was 10.19 and 0.97 %, respectively with result show little extent C: N ratio of about 10.50. This indicates the vermicompost that was applied to experimental field was well decomposed (Brady and Weil, 2002) recommends C: N ratio of below 20 to have good impact from application of compost. The concentration of available phosphorus was 12.69 ppm. The average pH (1:2.5 H_2O) was 7.8 where most essential plant nutrients are available for the crop. Likewise, (Goh and Haynes, 1977) reported similar result.

Chemical Properties of Soil

Organic Matter: Initial organic matter content of the soil was 2.44% before the addition of organic materials and this value changed depending on application doses. At the end of the experiment the highest organic matter 2.98% value was obtained with vermicompost applied in 9 t ha^{1} dose and the lowest value 2.61 was with the control treatment. This difference was found to be statistically significant (< 0.05). The combined result of three-year data show that, vermicompost increased the organic matter content depending on their application rate compared to the control.

However, no significant difference was observed between NP applied in the different doses. The data indicate that vermicompost application has significant effect on soil organic matter vermicompost can be considered as a good alternative to improve soil organic matter. Several reports support this conclusion and indicate that vermicompost improves soil physical and chemical properties by providing humus to soil (Nethra, et al. 1999).

Nitrogen: Initial total nitrogen percentage of the experimental field was 0.13 % found in low range Sahlemedhin (1999); Landon (1991) and Bruce and Rayment, (1982). At the end of the combined result of all year data revealed that, total nitrogen values ranged from 0.133% (the control) to 0.152% (6 t ha ^{1} vermicompost) (Table 4). Release of mineral nitrogen early in the process is caused when organic matter with a carbon: nitrogen ratio of less than 20 decomposes (Kirishan, 2005). When organic fertilizers are added to soil in order to fill organic matter storage, nitrogen is one of the major nutrients supplied to soil. Therefore, in our study, it was not impressing to observe that vermicompost upgrade the nitrogen content of soil. Even though 6 ton ha^{-1} VC showed high nitrogen content on the contrary 3,9,12 t ha^{-1} vermicompost recorded less than that. It was found that some of organic nitrogenous compounds in organic materials are converted to nitrogen and that this nitrogen is generally released slowly (Doube and Brown 1998).

Table 4. Effect of Vermicompost and NP on soil chemical property

NP	**N (%)**	**PH**	**P (ppm)**	**OC (%)**	**OM (%)**
0	0.141	5.872	4.849	1.664	2.868
50	0.142	5.847	4.980	1.564	2.697
100	0.145	5.851	5.143	1.678	2.892
LSD 5%	NS	NS	NS	NS	NS
VM					
0	0.133	5.843	4.370	1.518	2.616
3	0.139	5.852	4.973	1.609	2.773
6	0.152	5.875	5.244	1.708	2.943
9	0.145	5.833	5.173	1.735	2.989
12	0.145	5.880	5.194	1.608	2.772
LSD 5%	**NS**	**NS**	**NS**	**0.151**	**0.261**
NP*VM	**NS**	**NS**	**NS**	**NS**	**NS**
CV%	**18.49**	**2.12**	**26.82**	**17.15**	**17.16**

Available Phosphorus: Pre planting available phosphorus content of the soil was 4.1 ppm. At the end of the experiment, depending on time, the values varied between 4.97 ppm and 5.24 ppm (Table 4). According to (Olson, 1954) phosphorus level which observed in our study included under low level. The soil pH of our soil data indicated that a moderate range which was between 5.84-5.88 under these level macro nutrients was low. This study related to (D.A Horneck. et al, 2011) revealed that when soil pH is in between 5.2-6 the availability of P and N are decreased. Even though the P level was in low range the highest available phosphorus value was obtained with 6 t ha ^{1} vermicompost application and the lowest with the control. Where there was no significant difference between vermicompost by NP applied to soil as increased available phosphorus content compared to the initial soil data. The application of 100% NP (92N and 46$P_2O_5^{-1}$) increased by 1.04ppm of available phosphorous from the initial.

pH: Vermicompost applied in 12 t ha ^{1} dose resulted in higher soil pH values. Soil pH is an important soil property that has direct impact on plant growth, availability of nutrients, and microbial activity. It is generally thought that applications of organic materials like VC reduce soil pH. However, contrary to the general belief, we observed that soil pH in treatments with vermicompost almost above the control. This may be due to the fact that vermicompost used in our study have moderate alkaline reaction (Table 1). In fact, some researchers determined that organic fertilizers with high pH might not lower soil pH (Whalen and Carefoot 2000).

The Effects of Vermicompost and NP Fertilizer on Economic Feasibility of Wheat Production: Partial budget analysis of the combination of VM with NP fertilizer was presented in Table 5. The net benefit of ETB 62459.15 ha^{-1} and marginal rate return of 12.07 % was obtained from combination 9 ton with (50% NP) 46N and 23 P_2O_5kg ha-1. The net benefit ETB 48994.17 ha^{-1}, and the highest marginal rate return of 373.62% was gained from the use of 3ton VM with (100%NP) 92N and 46 P2O5kg ha-1 fertilizer.

Table 5. Partial budget analysis of VM and NP fertilizer for Wheat production

Tretment	TVC (ETB^{-1})*	GY ($kgha^{-1}$)	AdGY ($kgha^{-1}$)	STY ($kgha^{-1}$)	AdSTY ($kgha^{-1}$)	NB (ETB ha^{-1})	MRR %
0 tVM + 0N, P_2O_5	0	648.9	584	841	756.9	13388	
0 tVM + 46N,23 P_2O_5	1975	2088	1879.2	1170.3	1053.3	32119.66	3.38
0 tVM + 92N,46 P_2O_5	3950	3475.9	3128.3	1214	1092.6	48512.4	3.5
3 tVM + 0N, P_2O_5	1800	1587	1428.3	1373.3	1236	26944.16	13.28
3 tVM + 46N,23 P_2O_5	3775	2885	2596.5	1646.6	1481.9	43506.86	3.48
3 tVM + 92N,46 P_2O_5	5750	3372.1	3034.9	1835.6	1652	48994.17	373.62
6 tVM + 0N, P_2O_5	3600	1896.8	1707.1	2962.5	2666.3	38483.87	25.53
6 tVM + 46N,23 P_2O_5	5575	3291.9	2962.7	936.8	843.1	42864.58	D
6 tVM + 92N,46 P_2O_5	7550	3564.3	3207.9	1436.7	1293	47368.81	D
9 tVM + 0N, P_2O_5	5400	2174.9	1957.4	1305.1	1174.6	30617.28	D
9 tVM + 46N,23 P_2O_5	7375	4125.6	3713	2734.2	2460.8	62459.15	12.07
9 tVM + 92N,46 P_2O_5	9350	3339.6	3005.6	2281.5	2053.4	47578.56	D
12 tVM + 0N, P_2O_5	7200	1886.9	1698.2	1345.9	1211.3	25297.56	D
12 tVM + 46N,23 P_2O_5	9175	3167.2	2850.5	1609.6	1448.6	41573.12	D
12 tVM + 92N,46 P_2O_5	11150	3194.7	2875.2	1964	1767.6	42030.24	D

**AGY = Adjusted grain yield, GB (GY) = Gross benefit, TVC = Total variable costs, NB (Birr/ha) = Net benefit and MRR (%) = Marginal rate of return, D = Dominated treatment and ETB = Ethiopian Birr.*

Conclusion and Recommendation

Result on crops response to vermicompost and NP fertilizer rates is mandatory to come up with feasible and sustainable wheat production. The objective was to determine the effect of Vermicompost in relation to the NP fertilizer for wheat production in 2017-2019 GC. The interaction of VM and NP fertilizer application on wheat was found significant effect of biomass and grain yield of wheat. The combined result of three year data of vermicompst by NP fertilizer had no interaction effect. The combined analysis of variance of treatments over years showed significant. The results of soil pH, total nitrogen, organic matter and available P increased as compared from the initial. The combined application of 3ton with 100% NP ha^{-1} with the net benefit of ETB 48994.17 ha^{-1} and marginal rate return of 373.62 % was generated optimum grain yield and economically reasonable. Therefore, the combination 3ton with 100% NP ha^{-1} were recommended for the study location and similar agro-ecologies in bread wheat producing areas of Ethiopia.

Acknowledgements

We are grateful to the financial grant of Adet agricultural research center. We also acknowledge the staff and soil laboratory technicians of the center for their logistic supports and technical help during analysis of soil sample.

References

ATA (2014). Soil fertility status and fertilizer recommendation atlas for Tigray regional state, Ethiopia. MOA; ATA, Addis Abeba.

Atiyeh RM, Edwards CA, Subler S, Metzger JD (2001). Pig manure vermicompost as a component of a horticultural bedding plant medium: Effects on physicochemical properties and plant growth. Bioresour. Technol. 78(1):11-20.

Azarmi R, Giglou MT, Taleshmikail RD (2008). Influence of vermicompost on soil chemical and physical properties in tomato (Lycopersicum esculentum) field. Afri. J. Biotechnol. 7(14):2397-2401.

Brady, and Weil, RR. 2002. The Nature and Properties of Soils, 13th edition, Pearson Education, USA. 960p.

Bremner JM, Mulvaney CS (1982). Nitrogen- Total. In A.L. Page, R.H. Miller and D.R. Keeney (eds.). Methods of soil analysis. Part 2- Chemical and microbiological properties. Am. J. Agron. 9(2):595-624.

Bruce, R and Rayment, G. 1982. Analytical methods and interpretations used by the Agricultural Chemistry Branch for Soil and Land Use Surveys. Indooroopilly, Queensland: Queensland Department of Primary Industries.

CIMMYT (International maize and wheat improvement Center) (1988): From agronomic data to farmers recommendations. Economics training manual (completely revised ed.) D. F. Mexico: CIMMYT.

CSA (2019). Report on Area and production of major crops, Agricultural sample survey. Adiss abeba.

Davari MR Sharma SN Mirzakhani M (2012). The effect of combination of organic materials and biofertilizers on productivity, grain quality, nutrient uptake and economics in organic farming of wheat. J. Organic Syst. 7(2):26-35.

Doube and Brown.

Earthworm Ecology, C. Edwards, Ed., pp. 179 211, St Lucie Press, London, UK,.

Edwards CA, Burrows I (1988). The potential of earthworm composts as plant growth media. In: Earthworms in Environmental and Waste Management. C. A. Edward and J. Neuhauser. (Eds.). SPB Academic Publications. The Netherlands. Elmer WH, Pathology P, Connecticut T. A Experiment. Influence of Earthworm Activity on Soil Microbes and Soilborne Diseases of Vegetables. Am. Pathol. Soc. p. 38.

Edwards CA, Dominguez J, Arancon NQ (2004). Influence of vermicomposts on plant growth and pest incidence. In: SHS Hanna WZA Mikhail (eds). Soil Zoology for Sustainable Development in the 21st century. Cairo. pp. 397-420.

Edwards, C. A., Burrows, I., Fletcher, K. E. and Jones, B. A., 1985. The use of earthworms for composting farm wastes. In: J. K. R. Gasser, ed. Composting Agricultural and Other Wastes. London and New York: Elsevier, pp.229-241.

FAO (2019, Food and Agricultural organization of the United Nations Addis Abeba

Goh, K. M. and Haynes, R. J. 1977. Evaluation of potting media for commercial nursery production of con- tainer grown plants. New Zealand Journal of Agricul-tural Research. 20: 363 370.

Gruhn, P., Goletti, F. and Yudelman, M. (2000). Integrated Nutrient Management, Soil Fertility and Sustainable Agriculture: Current Issues and Future Challenges. International Food Policy Research Institute, Washington DC, USA.

Horneck, D.M. Sullivan, J.S. own and J.M. Hart. (2011). Soil test Interpretation guide.

Jayathilake, P.K.S., Reddy, I.P., Srihari, D. and Reddy, K.R., 2006. Productivity and soil fertility status as influenced by integrated use of n-fixing biofertilizers, organic manures and inorganic fertilizers in onion. *Journal of Agricultural Sciences – Sri Lanka*, 2(1), pp.46 58. DOI:

Joshi R, Vig AP, Singh J (2013). Vermicompost as soil supplementt to enhance growth, yield and quality of *Triticum aestivum*: A field study. Int. J. Rec. Waste in Agric. 2(16):1-7.

Kashem MA, Sarker A, Hossain I, Islam MS (2015). Comparison of the effect of vermicompost and inorganic fertilizers on vegetative growth and fruit production of tomato (*Solanum lycopersicum* L.) Open J. Soil Sci.5:53-58.

-

34,5th Main Road p9-29.

Landon, JR.(Ed.) 1991. Booker tropical soil manual: A Handbook for soil survey and Agricultural Land Evaluation in the tropics and sub tropics. Longman scientific and Technical, Essex, New York.47 p.

Mitchell A (1997). Production of Eisenia fetida and vermicompost from feed-lot cattle manure. Soil Biol. Biochem. 29(3-4):763-766. Kumar A, Pathak RK, Kumar S, Kumar K, Singh D, Pal S (2015). Influence of integrated nutrient management on yield, uptake and crop quality of wheat. Int. J. Res. Appl. 3(6):77-79.

Mitiku W, Tamado T, Singh TN, Teferi M (2014). Effect of Integrated Nutrient Management on Yield and Yield Components of Food Barley (Hordeum vulgare L.) in Kaffa Zone, Southwestern Ethiopia. J. Sci. Technol. Arts Res. 3(2):34-42.

a aster /*Callistephus chinensis* (L)/

Crop Research, vol.

17, pp. 209-215.

Olsen R., Cole S., Watanabe F. and Dean L. (1954). Estimation of available phosphorus in soils by extraction with sodium bicarbonate. United States Department of Agriculture Circ. 939.

Olsen, S. R. and Sommers, L. E. 1982. Phosphorus. pp. 403-430. In: A. L. Page, et al. (eds.) Methods of soil analysis: Part 2. Chemical and microbiological properties. Agron. Mongr. 9. 2nd ed. ASA and SSSA, Madison, WI.

Sahlemedhin, S. 1999. Draft guideline for regional soil testing laboratories. NFIA, Addis Ababa Ethiopia

Sangiga N, Woomer PL (2009). Integrated soil fertility management in Africa: Principles, practices and development process. Tropical soil biology and fertility program of the CIAT, Nairobi. 263p.

Seal A, Bera R, Sah KD, Sarkar D, Chatterjee AK (2014). Evaluation of Vermicompost as a Component of Integrated Nutrient Management in Wetland Rice under Saline. J. Recent Adv. Agric. 2(10):305-311.

Singh BK, Pathak KA, Verma AK, Verma VK, Deka BC, 2011. Effects of vermicompost, fertilizer and mulch plant growth, nodulation and pod yield of French bean (*Phaseolus vulgaris)*. Veg Crop Bulletin 74:153 165.

Singh CM, Sharma PK, Kishor P, Mishra PK, Singh AP, Verma R, Raha P (2011). Impact of Integrated Nutrient Management on Growth, Yield and Nutrient Uptake by Wheat (Triticum aestivum L). Asian J. Agric. Res.7:1-7.

Sinha RK, Sunil H, Valani D, Chauhan K (2009). Vermiculture and Sustainable Agriculture. Am. J. Agric. Environ. Sci. 5(55).

Whalen, c. chang, g.w. clayton, andj.p. C soil science society of america journal, vol. 64, no. 3, pp. 962 966,