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Response of bread wheat to integrated application of vermicompost and NPK fertilizers

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A greenhouse pot experiment was conducted to determine effects of vermicompost, inorganic fertilizers and their combinations on nutrient uptake, yield and yield components of wheat. A factorial combination four levels (0, 2, 4 and 6 tha-1) of vermicompost and four levels (0, 33.33, 66.67 and 100% ha-1) of the recommended NPK fertilizers was laid out in RCB design with three replications. Bread wheat variety, Kekaba was used as a test crop. Main effect results indicated that both vermicompost and NPK fertilizers significantly increased yield components, yield and nutrient uptake of wheat. Vermicompost applied at 2, 4 and 6 tha-1 increased grains yield of wheat by 11, 17 and 26% over control respectively whereas 33.33, 66.67 and 100% NPK fertilizers increased the grain yield by 10, 24 and 30%, respectively over the control. Vermicompost applied at 6 tha-1 resulted in the highest nutrient uptake and it increased grain uptake of N, P and K by 51, 110 and 89% over control respectively whereas among fertilizer rates, the highest uptake was produced by 100% NPK treatment and it increased the N, P and K uptake in the grain by were 79, 100 and 96% over control respectively. Combined application of vermicompost and NPK fertilizers has also significantly increased nutrient uptake, yield and yield components of wheat. It is concluded that wheat responds significantly to application of vermicompost and NPK fertilizers suggesting that nutrient contents of experimental soil is low for optimum production of wheat. Field verification and demonstration of results are recommended.

Key words: Soil fertility, Nutrient uptake, Grain and biomass yield, Yield components.

INTRODUCTION

Bread wheat is one of the major cereal crop produced in Ethiopia. According to central statistics authority (CSA) of Ethiopia, it is ranked fourth in terms of area cultivated and total production in 2014/2015 main cropping season (CSA, 2015). Wheat grains are 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. 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

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domestic need. Thus, it is forced to import 30 to 50% of its annual demand for wheat grain (White et al., 2001). The low productivity of wheat (<2 tha^{-1}) is the main reason for the current wide gap between demand and supply for wheat grain in Ethiopia.

Decline in soil fertility among others is the main cause of very low productivity 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 Ethiopia 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. Thus, developing site specific fertilizer recommendations are important for economic and environmental sound use of these inputs.

However, inorganic fertilizers were found to be more effective in increasing crop productivity when they are applied along with organic fertilizers. This is especially important for Ethiopia as nearly all soils in the arable lands of the country are highly depleted of organic matter. According to Gete et al. (2010), despite five times increase in fertilizer application in the Ethiopia, national cereal yields increased only by 10% since the 1980s. This was attributed to declining soil organic matter (IFPRI, 2010). This is because soil organic matter (SOM), in addition to improving the physicochemical properties of the soil and serving as nutrient sources, they hold nutrients from fertilizers applied in such a way that they are protected from loss through leaching and other pathways, and taken up by plants.

Organic fertilizers such as farm yard manure (FYM) and vermicompost 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 FYM that can supply adequate amount of nutrients needed by crops in smallholder famers' fields. Thus, integrate applications of inorganic and organic fertilizers are import 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 literatures indicating the multiple advantages with integrated application of organic and inorganic nutrient sources over that obtained with sole application of either source (Kumar et al., 2015; Singh et al., 2011; Sangiga and Woomer, 2009). Therefore, the objectives of this experiment were to determine the effects of integrated applications of vermicompost and NPK fertilizers on the yield components and yields of wheat and to determine the effect of integrated application of vermicompost and NPK fertilizers on the uptake of N, P and K by wheat.

MATERIALS AND METHODS

Brief descriptions of the study site

The experiment was conducted in the greenhouse at tissue culture micro-propagation laboratory, Mekelle, Northern Ethiopia. Composite soil samples for pot experiment were collected randomly from farmlands of Mekan village, Enda-Mehoni district, Southern Tigray, Ethiopia. The sampling sites were located between 12°43'28" to 12°46'12'' N and 39°29'18'' to 39°33'35'' E.

Physicochemical properties of soil and vermicompost used in this experiment

Prior to starting the experiment, the soil and vermicompost samples were analysed for their selected physicochemical properties following standard laboratory procedures (Jones, 2002) and the results are summarized in Table 1. The soil belongs to sandy clay loam textural class. The soil reaction (pH) was moderately alkaline and that of vermicompost was neutral (Tekalign, 1991).

Organic carbon (OC) content of the soil was found to be low whereas it was very high in vermicompost. Cation exchange capacity (CEC) of the soil was found to be high as outlined by (Hazelton and Murphy (2007). The soil TN content was in medium range but it was very high in the vermicompots (Berhanu, 1980). The available and total P contents of the soil and vermicompost were rated as medium (Cottenie, 1980) and very high (Murphy, 1968), respectively. Moreover, the total and exchangeable K contents of vermicompost and the soil were in medium ranges (FAO, 2006), respectively.

Treatments and experimental design

The treatments consisted of factorial combinations of four levels (0, 2, 4, and 6 tha^{-1}) of vermicompost (VC) and four levels (0, 33.3, 66.6, and 100%) of recommended NPK fertilizers. For vermicompost levels were coded as VC0, VC1, VC2, and VC3, whereas the fertilizer levels were coded as NPK0, NPK1, NPK2, and NPK3. The 100% recommended fertilizer rates (NPK3) for wheat production were equivalent to 64:20:50 kg NPK ha^{-1}. The experiment was laid out in RCB design with three replications.

Vermicompost was processed by earthworm *(Eisinea fetida)* using cow manure, *Lantana camara* leaves and wheat straw as main feedstock. Urea, TSP, and KCl were used as nitrogen (N), phosphorus (P), and potassium (K) sources in this experiment. Plastic pots with size 30 × 20 × 28 cm which were perforated at the bottom were filled up with 4 kg of soils. Then eight seeds of wheat variety, Kekaba were planted on pot as a test crop and later thinned to five seedlings after germination. The moisture contents of pots were regularly monitored and watered with distilled water as required.

Plant sampling and nutrient analysis

Plant samples were collected at harvest to determine the uptake of nitrogen, phosphorus, and potassium in the plant tissue. The above ground biomass of all the five plants from each pot were collected and partitioned into grain and straw. The grain and straw samples

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

Parameter	Sample source	
	Soil	Vermicompost (VC)
Textural class	Sandy clay loam	-
Moisture content (%)	-	38
pH	7.48	6.78
EC (ds m^{-1})	0.05	2.77
CEC (cmol(+) kg^{-1})	30.6	-
OC (%)	0.98	11.37
Total N (%)	0.06	1.41
Total P (%)	-	0.78
Av P (ppm)	9.26	-
Total K (%)	-	1.02
Exc.K (cmol(+) kg^{-1})	0.34	-

were washed with distilled water to clean contaminants, separately air-dried and oven dried to remove the moisture until constant weight was attained. The plant sample was ground and passed through 0.5 mm sieve for laboratory analysis. Plant phosphorus and potassium concentrations were analyzed through wet digestion method as described in Jones (2002). The P in the digest was determined by spectrophotometer, K by flame photometer and total nitrogen was analysed by Kjeldahl method (Bremner and Mulvaney, 1982).

Data collection

Data on total number of tillers per plant (TNTPP), effective number of tillers per plant (ENTPP), plant height (PHT), spike length (SPL), number of seeds per spike (NSPSP), above ground biomass (AGBYLD), and grain (GYLD) data were collected. The grain yield was divided to the biological yield and multiplied by 100% to calculate harvest index (HI) of wheat. Furthermore, nutrient (NPK) uptake data were obtained by multiplying the concentration of each nutrient in the straw and grain of wheat in each pot with the corresponding straw and grain yields.

Statistical data analyses

Data on yield component, AGBYLD, GYLD, HI, and nutrient uptake data 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 using the same software.

RESULTS AND DISCUSSION

Effects on yield components of wheat

The results of main effects data showed both vermicompost and NPK fertilizers significantly affected the yield component data of wheat grown in the greenhouse experiment (Table 2). VC3 produced the highest PHT, SPL, and NSPSP of wheat which was followed by VC2 and VC1 in that order and the least values of these parameters were produced in the control treatment. VC3 increased these parameters by 6, 16 and 36% over the control, respectively. However, vermicompost did not significantly affect TNTPP and ETNPP (Table 2).

On the contrary, NPK fertilizers significantly increased TNPP and ETNPP of wheat relative to the control treatment. The highest number of TNTPP (2.1) and ETNPP (1.9) were produced by NPK3 treatment. The results are in agreement with the findings of Niamatullah et al. (2011) who observed a significant difference in number of tillering and productive tillers of wheat due to NPK levels. This could be due to the priming effect of chemical fertilizers on availability of nutrients especially mineral N that could have contributed to the vegetative growth and tiller initiation of wheat unlike vermicompost. Similarly, PLH, SPL and NSPP of wheat have been significantly increased by all NPK fertilizer doses. The highest values of these parameters were produced by NPK and it increase PLH, PLH and NSPP by 14, 43 and 43% over the control, respectively. The magnitudes of increases in these parameters are far higher than that produced by the highest dose of vermicompost which is VC3. This happened due to immediate availability of nutrients contained in chemical fertilizers than those in the organic fertilizers such as vermicompost in this case.

PLH, SPL and NSPP of wheat have been significantly affected by interaction effects of vermicompost and NPK fertilizers (Table 3). All treatment combinations of vermicompost and NPK fertilizers significantly increased PLH, SPL, and NSPP of wheat compared to the control. However, the highest increases of the parameters were obtained with treatments involving VC3 + NPK3, VC2 + NPK2, and VC2 + NPK3 in that order. But these treatments were statistically at par among each other with respect to their effects on these parameters. The results are in agreement with several reports indicating that combined application of organic and inorganic fertilizers

Table 2. Main effects of vermicompost and NPK fertilizer levels on TNPP, ENTPP, PLH, SPL and NSPSP.

Treatment	TNTPP	ENTPP	PHT (cm)	SPL (cm)	NSPSP
Vermicompost level					
VC0	1.62[a]*	1.05[a]	65.45[b]	6.36[c]	23.33[c]
VC1	1.63[a]	1.07[a]	65.92[b]	6.96[b]	29.27[b]
VC2	1.70[a]	1.08[a]	69.38[a]	7.22[ab]	29.38[b]
VC3	1.73[a]	1.09[a]	69.35[a]	7.42[a]	31.85[a]
LSD (0.05)	ns	ns	2.92	0.35	2.26
NPK fertilizer level					
NPK0	1.00[c]	1.00[b]	61.43[c]	5.58d	17.27[c]
NPK1	1.54[b]	1.00[b]	67.51[b]	6.85[c]	28.05[b]
NPK2	1.96[a]	1.02[b]	71.12[a]	7.53[b]	34.14[a]
NPK3	2.17[a]	1.29[a]	70.05[ab]	7.99[a]	34.36[a]
LSD (0.05)	0.26	0.13	2.92	0.35	2.26
VC*NPK	ns	ns	*	**	*
CV (%)	18.99	15.16	5.19	6.08	9.55

*Means followed the same letter (s) are not significantly different each other at 0.05 probability level.

Table 3. Interaction effects of vermicompost and NPK fertilizers on PHT, SPL and NSPP.

Treatment combination	PHT (cm)	SPL (cm)	NSPSP
VC0 × NPK0	57.9[h]*	5.7[e]	15.1[f]
VC0 × NPK1	61.4[fgh]	5.5[de]	19.7[f]
VC0 × NPK2	69.9[abcd]	7.0[c]	27.9[e]
VC0 × NPK3	72.6[abc]	7.9[ab]	31.3[cde]
VC1 × NPK0	61.1[gh]	5.5[de]	16.8[f]
VC1 × NPK1	68.3[abcde]	6.9[c]	31.8[cde]
VC1 × NPK2	67.4[cde]	7.4b[c]	33.2[bcd]
VC1 × NPK3	66.9[cdefg]	7.9[ab]	35.2[abc]
VC2 × NPK0	62.6[efgh]	5.6[de]	17.9[f]
VC2 × NPK1	67.6[bcde]	7.8[abc]	29.1[de]
VC2 × NPK2	73.8[a]	7.5[bc]	37.4[ab]
VC2 × NPK3	73.5[a]	8.2[a]	33.1[bcd]
VC3 × NPK0	64.1[defg]	6.2[d]	19.3[f]
VC3 × NPK1	72.7[abc]	7.3[bc]	32.3[cde]
VC3 × NPK2	73.4[a]	8.3[a]	38.0[a]
VC3 × NPK3	67.2[cdef]	7.9[ab]	37.8[a]
LSD (0.05)	5.83	0.71	4.52
CV (%)	5.19	6.09	9.55

*Means followed the same letter (s) are not significantly different each other at 0.05 probability level.

produce significantly higher values of yield components of crops including wheat that obtained from sole application organic or inorganic fertilizers (Dastmozd et al., 2015; Yavarzadeh and Shamsadini, 2012).

Effects on biomass, grain yield, and HI

Main effects of vermicompost and NPK fertilizers on the biomass and grain yield of wheat are presented in Table 4. All vermicompost rates produced significantly higher AGBYLD and GYLD of wheat than the control. But the highest values of these parameters were obtained with VC3 followed by VC2 and VC1 in that order. This is in agreement with findings of Joshi et al., (2013) and Yousefi and Sadeghi (2014) who reported that application of vermicopost to soil significantly increases the yield of wheat. Besides, different studies have also

Table 4. Main effects of vermicompost and NPK on biomass and grain yield and harvest index (HI).

Treatment	AGBYLD (g pot^{-1})	GYLD (g pot^{-1})	HI (%)
Vermicompost level			
VC0	39.3[d]*	16.9[d]	42.7[b]
VC1	42.1[c]	18.6[c]	44.2[ab]
VC2	44.2[b]	19.6[b]	44.3[ab]
VC3	45.6[a]	21.1[a]	46.2[a]
LSD (0.05)	1.34	0.85	2.07
NPK fertilizer level			
NPK0	38.1[d]	16.4[d]	43.1[b]
NPK1	41.4[c]	18.0[c]	43.6[b]
NPK2	45.0[b]	20.3[b]	45.0[ab]
NPK3	46.8[a]	21.4[a]	45.6[a]
LSD (0.05)	1.34	0.85	ns
VCXNPK	**	ns	ns
CV (%)	3.75	5.36	5.62

*Means followed the same letters are not significantly different each other at 0.05 probability level.

demonstrated the beneficial effect of application of vermicompost at different rates on the yields of other crops such as tomato (Arancon and Edwards, 2005; Kashem et al., 2015), maize (Reshid, 2016), and barley (Mitiku et al., 2014). As vermicopost is a source of different essential plant nutrients, its application in soil with low nutrient content especially in NPK will definitely increase the growth, yield and yield components of crops including wheat.

However, in addition to being sources of different nutrients, vermicompost is also supposed to contain 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 effect of vermicompost on crops. Both vermicompost and NPK fertilizers have significantly increased HI of wheat (Table 4). VC3 produced the highest HI than that produced by all other treatments including control. Similarly, the highest HI was produced by NPK3 than that produced by all other treatment.

Similarly, all NPK fertilizers rates produced significantly higher ABGYLD and GYLD of wheat than the control (Table 4). NPK3 produced the highest yield than that produced by all other fertilizer treatments and it increased the AGBYLD and GYLD by 22.8 and 30.5% over the control, respectively. It also resulted in significantly higher HI value of wheat.

The positive effects of vermicompost and NPK fertilizers application on wheat seen in this experiment suggest that the study soils are low in its nutrient contents particularly of NPK. The result of initial soils analyses data (Table 1) also proves this claim.

Vermicompost by NPK fertilizer interaction effect was highly significant (P<0.001) for biomass yield of wheat (Table 5). Accordingly, the highest AGBYLD was produced by treatment involving VC2 + NPK3 which was statistical at par with biomass yield produced by VC3 + NPK2, VC1 + NPK3, VC2 + NPK2, and VC3 + NPK3 and all these treatments were statistically at par among each other with respect to ABYLD of wheat produced by them. However, they produced significantly higher ABYLD of wheat than that produced by sole application vermicompost and NPK fertilizers. The result suggests that there was a synergistic interaction between the two nutrient sources in availing nutrients to the growing wheat and the finding is in agreement with report of Davari et al (2012) and Davis et al. (2011). In line with the current finding, Seal et al. (2014) reported that straw yield, which is the major constituent of biological yield, was also significantly increased by the combined application of vermicompost and NPK fertilizers.

Effects on nutrient uptakes

The uptakes of N, P and K by the straw and grain yield of wheat were significantly affected (P ≤ 0.01) by the main effects of vermicompost and chemical fertilizers (Table 6). VC1, VC2, and VC3 increased grain N uptake by 22, 35, and 51%, respectively over the control. Similarly, these treatments increased the grain P uptake by 22, 45, and 71% over the control, respectively and the grain K uptake by 33, 48, and 53% over the control, respectively. There were also significant increases in the straw uptake of N, P and K due to vermicompost application. The apparent increased uptake of nutrients due to application VC indicates that there was net mineralization of nutrients from vermicompost.

Table 5. Interaction effects of vermicompost and NPK fertilizers on AGBYLD (g pot^{-1}) of wheat.

NPK fertilizer level	Vermicompost Levels				
	VC0	VC1	VC2	VC3	Mean
NPK0	34.57^{h}*	35.47^{h}	38.77^{fg}	43.60^{dc}	38.10
NPK1	36.90^{gh}	41.47^{de}	43.07^{cde}	44.03^{dc}	41.37
NPK2	40.50^{ef}	44.57^{bc}	47.03^{ab}	47.90^{a}	45.00
NPK3	45.13^{bc}	46.93^{ab}	48.10^{a}	46.93^{ab}	46.77
Mean	39.28	42.11	44.24	45.62	42.81

*Means followed the same letter (s) are not significantly different each other at 0.05 probability level.

Table 6. Effects of vermicompost and NPK fertilizers on uptake of N, P and K by grains and straw of wheat.

Treatment	Nutrient uptake					
	Nitrogen (g pot^{-1})		Phosphorus (g pot^{-1})		Potassium (g pot^{-1})	
	Straw	Grain	Straw	Grain	Straw	Grain
Vermicompost level						
VC0	0.055^{c}*	0.306^{d}	0.007^{c}	0.009^{d}	0.432^{c}	0.08^{d}
VC1	0.078^{b}	0.373^{c}	0.011^{a}	0.011^{c}	0.476^{b}	0.107^{c}
VC2	0.091^{a}	0.412^{b}	0.009^{b}	0.014^{b}	0.514^{a}	0.132^{b}
VC3	0.098^{a}	0.462^{a}	0.011^{a}	0.019^{a}	0.543^{a}	0.151^{a}
LSD (0.05)	0.008	0.0375	0.001	0.0012	0.0368	0.0107
NPK fertilizer level						
NPK0	0.044^{d}	0.28^{d}	0.007^{b}	0.009^{d}	0.400^{d}	0.082^{d}
NPK1	0.068^{c}	0.35^{c}	0.008^{b}	0.011^{c}	0.472^{c}	0.098^{c}
NPK2	0.093^{b}	0.422^{b}	0.012^{a}	0.015^{b}	0.525^{b}	0.131^{b}
NPK3	0.116^{a}	0.502^{a}	0.012^{a}	0.018^{a}	0.568^{a}	0.161^{a}
LSD (0.05)	0.008	0.0375	0.001	0.0012	0.0368	0.0107
VC × Fertilizers	*	ns	**	ns	ns	ns
CV (%)	11.96	11.60	12.84	11.02	9.01	10.95

*Means followed the same letter (s) are not significantly different each other at 0.05 probability level.

Similarly, all NPK treatments have significantly increased the uptake of N, P and K by the straw and grain of wheat compared with the control or NPK0 (Table 6). However, the highest uptake of N, P and K by straw and grain of wheat was produced by NPK3 followed by NPK2 and NPK1 in that order. These treatments increased the grain N uptake by 79, 50 and 25% over the control (NPK0), respectively. These treatments increased the grain P uptake by 100, 67, and 22% over the control, respectively and the grain K uptake by 96, 60, and 20% over the control, respectively. The finding is in line with Sheoran et al. (2015) and Laghari et al. (2010) who reported that applications of NPK have significantly increased grain nutrient uptake of wheat.

Conclusion

Application of vermicompost significantly increased the yield components, yield and nutrient uptake of wheat grown in the greenhouse suggesting that there was net mineralization of nutrients contained in the vermicompost and availed to the growing wheat. The results also suggest that the soil used in the experiment was low in essential plant nutrients. Similarly, application of NPK fertilizers significantly increases the yield components, yield and nutrient uptake of wheat indicating insufficient amount of N, P and K in soil used in the study. This was confirmed by results of initial soil analyses data of experimental soil which showed that low levels of N, P and K as well as low level of soil organic matter content.

There was a significant interaction between vermicompost and NPK fertilizers for above ground biomass yield of wheat and optimum yield was produced by treatment combination of VC2 + NPK2. The result suggests that there was synergistic interaction between vermicompost and NPK fertilizer in increasing nutrient availability to the growing wheat. The finding further indicates that the full recommended dose can be decreased to 67% and the vermicompost dose can be decreased by 50% to achieve the same yield produced by 100% vermicompost and NPK fertilizer doses applied alone. Further verification and demonstration of the current results in the field are recommended.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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