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Yield and Nitrogen Uptake of Wheat as Affected by Nitrogen Fertilizer and Compost in the Central Rift Valley of Ethiopia

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የተፈጥሮንና የኬሚካል ማዳበሪያን አቀናጅቶ መጨመር የአፈርን ንጥረ-ነገር በሰብል የመጠቀም ሁኔታና ምርትን ይጨምራል፡፡ ሆኖም ግን የአፈርን ዓይነት፣ የተለያዩ ሰብሎችንና አካባቢን ግምት ውስጥ ያስገባ የሁለቱን ማዳበሪያዎች መስተፃምር የመለየት ምርምር ሥራ ብዙ አልተካሄደም፡፡ በዚህም ምክንያት የኮምፖስትንና የኬሚካል ናይተሮጅን ማዳበሪያዎች መስተፃምርና መጠን እንዲሁም አዋጭነቱን ለመለየት በስንዴ ሰብል ላይ መስኖ ውሃ በመጠቀም በመልካሳ ግብርና ምርምር ማዕከል በ2006 ዓ.ም. ጥናቱ ተከናውኗል፡፡ ለዚህም ጥናት አራት የተለያየ የኬሚካል ናይተሮጅን ማዳበሪያ መጠን (0፣ 23፣ 46 እና 69 ኪ.ግ ለአንድ ሄክታር) እና አራት የተለያየ የኮምፖስት መጠን (0፣ 5.6፣ 11.2 እና 16.8 ቶን ለአንድ ሄክታር) አቀናጅቶ ማሳ ላይ በመጨመር ተከናውኗል፡፡ የጥናቱ ውጤት እንደሚያሳየው ኮምፖስትን እና ኬሚካል ናይተሮጅን ማዳበሪያን ለየብቻም ሆነ ሁለቱን ማዳበሪያዎች አቀናጅተን ስንጨምር በስንዴ ምርትና የሰብሉን ናይተሮጅን ንጥረ-ነገር አጠቃቀም ላይ ጥሩ የሚባል መሻሻል አሳይቷል፡፡ ነገር ግን ሁለቱን ማዳበርያዎች ለየብቻ በመጨመር ከተገኘው ውጤት በተሻለ ሁኔታ ኮምፖስትንና ኬሚካል ናይተሮጅን ማዳበሪያን በቅንጅት የተጨመረው ከፍተኛ የሆነ የስንዴ ምርት አስመዝግቧል፡፡ በተለየ ሁኔታ 69 ኪ.ግ ኬሚካል ናይተሮጅን ማዳበሪያን እና 5.6 ቶን ኮምፖስትን በአንድ ላይ በቅንጅት የተጨመረው ተመጣጣኝና አዋጭ የሆነ የስንዴ ምርት አስገኝቷል፡፡ በተጨማሪም ሁለቱን ማዳበርያዎች ለየብቻ ከተጨመረው የልቅ ኮምፖስትንና ኬሚካል ናይተሮጅን ማዳበሪያን በቅንጅት የተጨመረው በተሻለ ሁኔታ የሰብሉን የናይተሮጅን ንጥረ-ነገር አጠቃቀም ጨምሯል፡፡ ስለዚህ ከዚህ ጥናት ማጠቃለል የሚቻለው 69 ኪ.ግ ኬሚካል ናይተሮጅን ማዳበሪያን እና 5.6 ቶን ኮምፖስትን አቀናጅቶ መጠቀም፤ ዘላቂ የሆነ የአፈር ማዳበሪያ አማራጭ መሆኑን ነው፡፡

Abstract

Integrated applications of organic and inorganic nutrient sources are indispensable for enhanced nutrient use efficiency and crop yields. However, it requires determination of the optimum combination of these resources based on soil type, crop species, and location. Cognizant of this fact, an experiment was conducted to determine the optimum levels and combinations of compost and inorganic N fertilizers for maximum profitable grain yield of wheat at Melkassa under irrigation in 2014. The experiment involved factorial combinations of four rates of N (0, 23, 46 and 69 kg ha^{-1}) and four levels of compost (0, 5.6, 11.2, and 16.8 t ha^{-1}) laid out in RCB design with three replications. The results revealed that both chemical N and compost and their interactions significantly and positively affected the yield of wheat and N uptake. The highest grain yield was obtained from the combined applications of chemical N and compost than that obtained from N and compost applied alone. Accordingly, combinations of 69 kg N ha^{-1} and 5.6 t ha^{-1} produced optimum grain yield and realized the maximum net returns of wheat. Significantly, higher N uptake was obtained from the combined application of N and compost than that obtained from either source applied alone. Therefore suggested that combination of 69 kg mineral N ha^{-1} and 5.6 t ha^{-1} compost are the best combination to achieve sustainable yield.

Introduction

Declining soil fertility is one of the most significant constraints to increased food production in Ethiopia (Gete *et al*., 2010; Getachew and Tilahun, 2017). Anthropogenic factors such as inappropriate land use systems, mono cropping, nutrients mining and inadequate supply of nutrients have aggravated the situation. In order to increase soil fertility in the short run, nutrients have to be added to the soil. This is often done by applying chemical fertilizers. Chemical fertilizers, however, are expensive to purchase and for most small-scale farmers this is a problem (Gete *et al*., 2010; Getachew and Tilahun, 2017). Hence, to sustain the balance of soil fertility and to ensure agricultural productivity adoption of composting technology and application of amenable compost is quite essential.

Compost is one of the main sources of plant nutrients as organic fertilizer contributing to increased crop productivity and sustainable agriculture. It is made from plant and animals residues with the objectives of recycling these remains for crop production. Compost consists of the relatively stable decomposed organic materials resulting from the accelerated biological degradation of organic materials under controlled, aerobic conditions (Paulin and Peter, 2008). The decomposition process converts potentially toxic or putrescible organic matter into a stabilized state that can improve soil for plant growth.

However, compost releases nutrients very slowly to the plants and these nutrients are not directly absorbed by the plants. Therefore, plants are unable to access the required amount of nutrients in the critical yield-forming period. Fertilizer equivalency values of organic resources are directly related to nitrogen content in the organic material (Kimetu et al. 2004; Getachew and Taye, 2005). Since the nutrient content of compost is low compared to synthetic fertilizer products, it is usually applied at higher rates and therefore nutrient contribution can be significant. Nevertheless, applying large quantity of compost is difficult under Ethiopian farmers' condition due to competing uses for crop residues and manure as livestock feed and fuel, respectively (Tolera *et al*., 2005; Gete et al., 2010; Getachew *et al*., 2014). Furthermore, adding artificial fertilizer alone is not sufficient to maintain a sufficient level of nutrients in the soil. Organic matter is needed to retain water and nutrient in the soil. In a degraded soil, where there is little organic matter, yield response is limited, even if artificial fertilizers are being used (Madeleine *et al*., 2005; Getachew *et al*., 2016).

Hence, the higher the price of chemical fertilizers and the higher demand for organic residue in the field would require the combined use of compost with inorganic fertilizer. Such combination contributed to the improvements of soil biophysical and chemical properties, soil organic matter content and nutrient status. According to Getachew et al. (2012), the application of half the recommended rate of NP fertilizer with 50% of the recommended dose of compost (3 t ha^{-1}) can be an alternative best integrated soil fertility management approach instead of applying only inorganic fertilizers for sustainability. Moreover, in spite of the advice given to farmers' to prepare and use compost for their crops, information on the impact of sole compost and/or integrated use of compost with inorganic fertilizer on performance of wheat productivity, particularly in the moisture stressed and irrigated areas, is lacking. In view of this fact, systematic investigations into compost and N mineral fertilizers combinations are of paramount importance for rationalizing the application of compost and N mineral fertilizers to optimize wheat production. Hence, this study was initiated with the following specific objectives: to determine the effect of compost and inorganic N fertilizers on yield of wheat and N-uptake and to determine the optimum levels and interaction effect of compost and inorganic N fertilizers for maximum profitable grain yields of wheat.

Materials and Methods

The study area

The experiment was carried out at the experimental field of Melkassa Agricultural Research Center (MARC), East Shewa Zone of Oromiya Regional State. The center is found near Awash Melkassa (8^{o}24'N latitude and 39^{o}12'E longitude), that is 17 km southeast of Nazareth town and 107 km away from Addis Ababa. The area is situated at an altitude of 1550 m. The average annual rainfall is 767 mm, while the annual mean maximum and minimum air temperatures are 28.6^{o}C and 13.8^{o}C, respectively. The soils of MARC farm is dominantly andosol with loam and clay loam in texture. Chemical properties of the experimental soil and compost were determined before planting (Table 1).

Table 1. Chemical properties of the soil and compost prior to planting

Type	pH	OC	TN	C/N	Avail. P	Basic cations and CEC (cmol(+)kg^{-1})				
	(H_20)	(%)	(%)	ratio	(ppm)	Ca	Mg	K	Na	CEC
Soil	7.0	1.30	0.071	18.31	17.64	21.60	2.40	2.19	0.77	26.96
Compost	7.2	4.80	0.414	11.58	195.90	37.40	4.70	11.53	1.15	53.63

OM = Organic matter, TN = Total nitrogen; C/N = Carbon to nitrogen ratio; Avail. P = Available phosphorus and CEC= Cation exchange capacity

Experimental treatments, design and procedures

A field experiment was conducted using a factorial experiment involving 4 x 4 combinations of compost and inorganic N fertilizer in a randomized complete block design with three replications. The treatments included combinations of four different rates of inorganic N fertilizer (0, 23, 46, 69 kg N ha^{-1}) and four different N based application rates of compost rate (0, 23, 46, 69 kg N ha^{-1}) which was equivalent to compost rate (0, 5.6, 11.2 and 16.8 t ha^{-1}) respectively. The recommended phosphorus fertilizer (20 kg P ha^{-1}) was applied uniformly to all plots at the time of planting.

The compost was prepared following the standard procedure of Melkassa Agricultural Research Center (MARC) (EIAR, 2009). Samples collected from well-decomposed compost were analyzed for total N before the onset of the trial to calculate N based rate of compost using Kjeldahl method. Finally, the moisture content calculated from the fresh and oven dry weights was used to determine the different rates of compost to be applied for each treatment on a dry weight basis. Compost was applied 7 days before sowing and thoroughly mixed in the upper 15cm soil depth. This process was supposed to facilitate nutrient release for the crop after germination. Nitrogen and P fertilizers were applied in the form of urea and TSP respectively. To minimize loss and increase efficiency of N, it was applied as a split half dose at planting and the remaining half during the maximum growth period of the crop (tillering stage). Wheat (*T. aestivum L.* var. Gambo) was planted at the recommended seed rates and sowing dates. Other recommended agronomic practices were applied during the crop growth period according to common practices.

Data collection

Measurements

Grain and total biomass yields of wheat were determined by harvesting the entire net plot of 2.7 m^2 and converted into kg ha^{-1} for statistical analysis. Total biomass was recorded on air dry-weight basis one week after harvesting to get constant weight, and grain yield was adjusted to 12.5% moisture content.

The samples of straw and grains of wheat at maturing stage were ground to 40 mesh powder in the Wiley mill and Nitrogen was determined by Kjeldhal digestion method (Van, 1992). Below equations also were used to determine N-uptake, apparent nutrient recovery and agronomic efficiency.

$$N\ uptake = \text{N concentration in treatment sample} \times \text{Grain/ straw yield in plot}$$

$$\text{Agronomic Efficency (AE)} = \frac{\text{Grain yield}_f - \text{Grain yield}_c}{\text{Fertilizer N applied}}\ \text{kg/kg}$$

$$\text{Apparent Nutrient Recovery(ANR)} = \frac{\text{N uptake}_f - \text{N uptake}_c}{\text{Fertilizer N applied}}\ \text{kg/kg}$$

Where the indices, f and c denote ‘fertilized crop’ and ‘unfertilized controls’ respectively (Shehu, 2014).

Economics analysis

Economics analysis was also conducted to investigate the economic feasibility of the treatments, i.e. partial budget, dominance and marginal rate of returns were performed (CIMMYT, 1988). The mean grain yields were adjusted downwards by 10% to reflect the difference between the experimental plot yield and the yield farmers could expect from the treatment. Total cost included all the expenses for buying and applying the mineral fertilizers and the labor for collection, composting, transporting and application of organic source. According to Tolera and Mathewos (2006), the value of wheat straw was also included in the current economic analysis. The gross benefit was calculated as an average adjusted grain yield (kg ha^{-1}) x field price that farmers receive for the sale of the crop (10.0 ETB kg^{-1}). Total variable cost was calculated as the sum of all costs, i.e. variable or specific to a treatment against the control. Net benefit was also calculated by subtracting total variable cost from the gross benefit. The marginal rate of return (MRR) was calculated as the ratio of differences between net benefits of successive treatments to the difference between total variable costs of successive treatments. Treatments with higher cost and with lower net benefit than the previous successive treatments are indicated as dominated (D). For a treatment to be considered a worthwhile option to farmers, the minimum acceptable rate of return (MARR) needs to be between 50% and 100% (CIMMYT, 1988). However, the MARR of 100% was suggested as realistic (Minale *et al.*, 2004; Getachew *et al.*, 2012). Hence, to make recommendations from marginal analysis, the MARR was taken to be 100%.

Statistical analysis

The results of the field experiment were subjected to analysis of variance using SAS software program, version 8.2 (SAS Institute, 2000). Significant differences between treatment means was compared and separated using the least significant difference (LSD) test at the 0.05 and 0.01 probability levels (Gomez and Gomez, 1984). The plant tissue analysis were interpreted using descriptive statistics.

Results and Discussion

Interaction effect of compost and inorganic N fertilizer

Results showed that compost by inorganic N fertilizer interaction significantly ($P < 0.01$) affected grain and total biomass yields of wheat (Figure 1). When compost and N fertilizers interaction increased from no compost x N applied to 16.8 t compost x 46 kg N ha^{-1} wheat grain yields was significantly increased from 1.54 to 3.7 t ha^{-1}. However, when it increases further the grain yield decreases significantly. The highest yield was observed from the application of 46 kg N ha^{-1} as inorganic and 16.8 t ha^{-1} as organic form, followed by the combined applications of 69 kg N ha^{-1} and 5.6 t ha^{-1}, 69 kg N ha^{-1} and 11.2 t ha^{-1}, and 23 kg N ha^{-1} and 16.8 t ha^{-1}, whilst no significant differences were observed between themselves. The lowest grain yield of 1.54 t ha^{-1} was recorded from the control treatment, which differed significantly from all other treatments. In addition, the combined application of 46 kg N with 16.8 t ha^{-1} resulted in yield advantages of about 140% and 23% over the control and the highest N rate (69 N ha^{-1}), respectively. This implies that the integration of organic and inorganic sources improved nutrient use efficiency by plants; as a result, the wheat grain yield was increased.

Similarly, the interaction of mineral N fertilizer and compost significantly ($P \leq 0.05$) improved total biomass yield of wheat (Figure 2). The trend of response was very clear, where the highest biomass yield of 9.42 t ha^{-1} was obtained from the combined application of 69 kg N ha^{-1} and 11.2 t ha^{-1} compost, while the lowest biomass yield obtained from the control treatment (without mineral N and compost). Thus, the combined application of 11.2 t ha^{-1} compost and 69 kg N ha^{-1} increased wheat total biomass yield by 141% compared to the control treatment, followed by yield increments of 130% and 128% due to the combined applications of 16.8 t ha^{-1} compost and 46 kg N ha^{-1}, and 5.6 t ha^{-1} compost and 69 kg N ha^{-1}, respectively. Accordingly, the yield obtained from the control treatment was significantly lower ($P < 0.05$) than the biomass yields obtained from either the separate or combined application of compost and inorganic N fertilizer. Overall, the total biomass increased as the combined levels of applied inorganic

N and compost increased up to 11.2 t ha^{-1} and 69 N kg ha^{-1}, but decreased afterwards. These results showed consistent with grain yield.

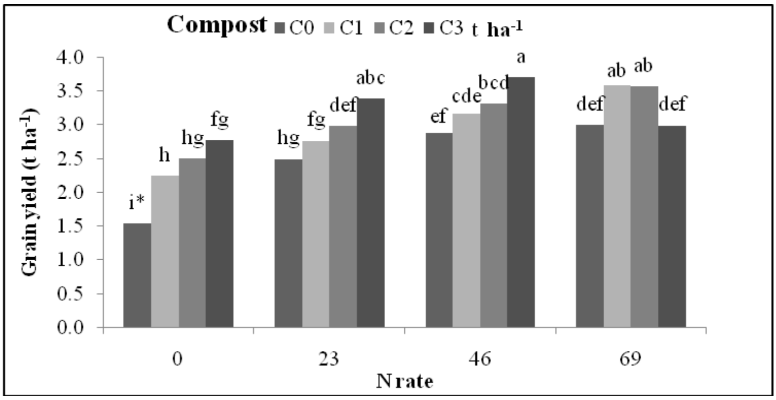

Figure 1. Interaction effects of compost and N fertilizers on grain yield of wheat at Melkassa, Central Rift Valley of Ethiopia. **Bars followed by the same letter (s) are not significantly different from each other. CO= no compost, C1=5.6 t ha^{-1}, C2=11.2 t ha^{-1}, C3=16.8 t ha^{-1}*

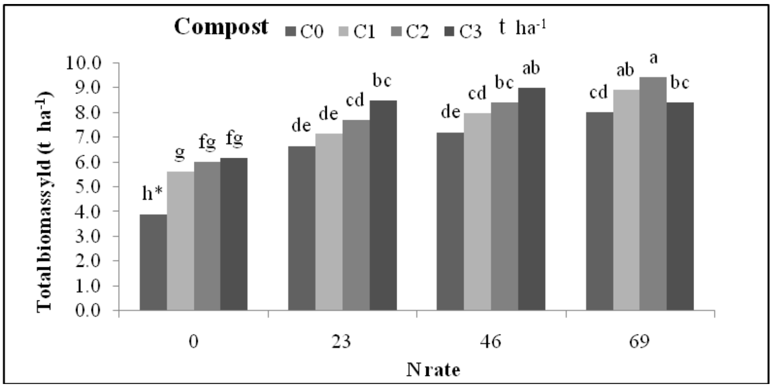

Figure 2. Interaction effects of compost and N fertilizers on total above ground biomass yield of wheat at Melkassa, Central Rift Valley of Ethiopia. **Bars followed by the same letter (s) are not statistically different from each other, CO= no compost, C1=5.6 t ha^{-1}, C2=11.2 t ha^{-1}, C3=16.8 t ha^{-1}*

In agreement with this result, Getachew *et al*. (2014) indicated that application of half the recommended NP rate (30 kg N/10 kg P ha^{-1}) and half the recommended rate of manure and compost as inorganic N equivalence (3.25 t ha^{-1}) resulted in wheat grain and total biomass yield advantages of about 129% and 94% compared to the control, respectively. Their findings have also shown that application of 50% recommended NP rate and 50% manure and compost as inorganic N equivalence resulted in tef grain and total biomass increments of 113 and 122% compared to the control, respectively. Similarly, Zahir *et al*. (2007) reported wheat yield increment of 102% over the control due to the application of N-enriched compost (with 25% N) supplemented with 60 kg ha^{-1} N fertilizer, which was not significant from full dose of N fertilizer. Tayebeh et al. (2010)

also reported the positive interaction effects of inorganic N and compost indicating that the maximum wheat grain yield was obtained from the application of 30 Mg ha^{-1} compost and 160 kg N ha^{-1}. Moreover, Zahir Shah *et al*. (2007) suggested that integrated use of urea and compost at 75:25 or 50:50 ratios (N basis) has produced maximum yields and is therefore recommended for profitable maize yield and sustainable soil fertility.

In order to preserve the environment and the present natural resources, further increases in global wheat production must be along with a proper management of fertilization. Integrated use of organic wastes and chemical fertilizers is beneficial in improving crop yield, soil pH, organic carbon and available N, P and K in soil (Wakene *et al*., 2001; Getachew *et al*., 2014). The results of the present experiment indicated that wheat grain yield and total biomass increased significantly with the application of N fertilizer and compost (Fig. 3 and 4). However, yield increments were not significant due to the applications of the highest levels of N and compost (69 kg N and 16.8 t ha^{-1}. Excess application of both nutrient sources suppressed the grain production, probably due to lush green vegetative growth that was observed during the growing season (Mohammed et al., 2004).

The results of this study showed that the use of chemical N fertilizer in combination with compost consistently enhanced yield and yield components of wheat compared to either compost or inorganic N fertilizer applied alone. This could be an indication of better results in combining organic and inorganic N source, which could be attributed to better synchrony of nutrient availability to wheat crop demand. Other researchers also reported similar results (Sarwar *et al*., 2008; Tayebeh *et al*., 2010; Fanuel and Gifole, 2012; Getachew *et al*., 2012). Haile (2012) showed that the combined applications of 10 t ha^{-1} *Erythrina bruci* biomass + half of the recommended dose of inorganic fertilizers (46 kg N ha^{-1} and 40 kg P ha^{-1}) on Nitisols of southern Ethiopia increased wheat grain yield by 173% over the control and gave superior yield than either input applied alone. Besides, the positive effect of organic fertilizer on soil structure that lead to better root development can result in improved nutrient uptake; compost not only slowly releases nutrients but also prevents the losses of chemical fertilizers through denitrification, volatilization and leaching (Zahir *et al*., 2007). It is very likely that when we apply compost along with chemical fertilizers, compost prevents nutrient losses.

Plant nitrogen concentration and uptake

Data on Table 2 shows the concentration and uptake of N by wheat plants as influenced by the separate and combined application of inorganic N fertilizer and Compost. The combined application of mineral fertilizer at the rate of 46 kg N ha^{-1} and 16.8 t ha^{-1} compost resulted in the highest total N uptake value of 102.6 kg N ha^{-1} which is obviously attributed to improved availability of the nutrient followed by 94.84, 89.00 and 80.00 kg N ha^{-1} with the respective applications of 69 N kg ha^{-1} and 11.2 t ha^{-1} compost , 69 N kg ha^{-1} and 5.6 t ha^{-1} compost, and 23 N kg ha^{-1} and 16.8 t ha^{-1} compost. The lowest total N uptake of 29.93 kg N ha^{-1} was recorded from the control (with no application of N and compost). It was also apparent that much more of the nutrients applied were assimilated by the grain than that achieved by the straw. The overall result of total N uptake in this study revealed that N uptake increased as the use of compost in combination with inorganic N sources increased . However, when the highest levels of 69 kg N and 16.8 t ha^{-1} compost were applied in combination, the N uptake tended to decrease. In agreement with these result, Dong *et al*. (2013) indicated that excess N application resulted in more residual fertilizer N and NO_3-N in soil, the N uptake did not increase, and grain yield even decreased.

Table 2. Plant N concentrations and uptakes as influenced by applied organic and inorganic nutrient sources

Treatment		N concentration (%)		N uptake (kg ha^{-1})	
Compost rate (t ha^{-1})	N rate (kg ha^{-1})	GNC	SNC	GNU	SNU
0	0	1.60	0.22	24.69	5.23
5.6	0	1.71	0.25	38.25	8.42
11.2	0	1.75	0.27	43.86	9.25
16.8	0	1.78	0.32	49.42	10.64
0	23	1.70	0.26	42.21	10.62
5.6	23	1.75	0.28	48.30	12.26
11.2	23	1.89	0.32	56.20	14.94
16.8	23	1.94	0.30	65.63	15.17
0	46	1.78	0.31	51.20	13.34
5.6	46	1.78	0.31	56.24	14.77
11.2	46	1.80	0.32	59.47	16.21
16.8	46	2.21	0.39	81.92	20.68
0	69	2.00	0.28	59.93	13.79
5.6	69	1.99	0.32	71.44	17.56
11.2	69	2.02	0.39	71.90	22.93
16.8	69	1.99	0.34	59.37	18.18

*****GNC = Grain N concentration; SNC = Straw N concentration; GNU=Grain N uptake, SNU=Straw N uptake*

Generally, higher total N concentrations and uptake values were obtained from the combined application of compost and mineral N fertilizers than application of mineral N fertilizer or compost alone. This may be attributed to the complementary effects of the two nutrient sources in improving the overall soil environment whereby the inorganic N source provides a more readily available N nutrients in adequate quantity. The nutritional status of plants was further strengthened when chemical fertilizer was combined with compost (Sawer *et al*., 2009). Previous studies have also shown that composted organic materials enhance fertilizer use efficiency by releasing nutrients slowly, and thus reducing the losses, particularly of N (Ramos and Marttinez-Casasnovas, 2006). This may be attributed to the improvement of soil physical properties by the organic nutrient sources in addition to contributing to nutrient availability (Amlinger *et al*., 2007; Laila, 2011).

Agronomic efficiency

Agronomic efficiency as affected by various mineral N and organic source and their combination is presented in table 3. Maximum agronomic efficiency of (40.72 kg kg^{-1})

was observed in the treatment to which 23 kg^{-1} mineral nitrogen was applied followed by 30.15, 28.99 and 26.38 kg^{-1} with the respective applications of 5.6 t ha^{-1} compost, 46 N kg ha^{-1}, and 23 N kg ha^{-1} and 5.6 t ha^{-1} compost. The lowest agronomic efficiency of 10.46 kg^{-1} was recorded from combined application of the highest rate of both nutrient sources (69 N kg ha^{-1} and 16.8 t ha^{-1} compost).

The agronomic efficiency of applied N exhibited a decreasing trend in response to higher mineral N and organic application level. Similar findings on agronomic efficiency of N were reported when N supplied from organic and inorganic sources and the authors stated that agronomic efficiency of N decreased when N fertilization increased (Kyi et al. 2017). Nano (2017) also reported a decreasing trend in agronomic efficiency with increasing N levels. Accordingly, the highest (40.72 kg kg^{-1}) agronomic efficiency was obtained at the lowest (23 kg N ha^{-1}) N level. The results indicated efficient use of nitrogen at lower rate of application (23 kg N ha^{-1}), which is in agreement with previous results reported by other investigators (Nano et al., 2017). On the other hand, the decrease in agronomic efficiency with increasing levels of N applied is remarkably different from the report of Gebreyes (2008), who reported higher agronomic efficiency under the application of higher levels of nitrogen.

Comparing the individual sources, the organic source cannot compete with mineral fertilizer, as the nutrients are easily available to the crops from the mineral source than the organic source. Kyi et al. (2017) had also observed that lowest agronomy efficiency and apparent nutrient recovery were recorded from FYM and urban garbage compost application.

Apparent nutrient recovery

The highest apparent recovery of N was attained in plots amended with mineral N alone at the rate of 23 kg N ha^{-1}. Additionally, plots amended with sole compost application (5.6 t ha^{-1} compost) showed the third higher apparent recovery of N as compared to those with combined applications of compost with mineral N and the rest sole compost and mineral N fertilization (Table 3).

Table 3. Agronomic efficiency and recovery as influenced by organic and inorganic nutrients

Treatment		Agronomic efficiency (kg kg^{-1})	Apparent N recovery (kg kg^{-1})
Compost rate (t ha^{-1})	N rate (kg ha^{-1})		
0	0	-	-
5.6	0	30.15	0.73
11.2	0	20.87	0.50
16.8	0	17.83	0.44
0	23	40.72	1.00
5.6	23	26.38	0.67
11.2	23	20.77	0.60
16.8	23	20.07	0.55
0	46	28.99	0.75
5.6	46	23.53	0.60
11.2	46	19.24	0.50
16.8	46	18.78	0.63
0	69	21.06	0.63
5.6	69	22.25	0.64
11.2	69	17.59	0.56
16.8	69	10.46	0.35

Like the agronomic efficiency of applied nitrogen, the apparent recovery of N also decreased at higher rates than at lower rates application of mineral and organic N and their combination. The highest apparent recovery of N at 23 kg N ha^{-1} could be related to the efficient use of the applied rate, while the least recovery at 69 N kg ha^{-1} and 16.8 t ha^{-1} compost in the above-ground biomass may suggests that N may pose an environmental risk. One explanation for the low nutrient recovery is also the large N mineralization potential of these soils, which results in significant N uptake in the unfertilized plants. Moreover, compost N applied, but not taken up by the crop, are vulnerable to losses from leaching, erosion, and denitrification or volatilization, or it could be temporarily immobilized in soil organic matter to be released later (Dong et al., 2013).

Economics analysis

The results of the marginal analysis for the non-dominated treatments indicated that the highest net benefit of birr 30917.25 with acceptable MRR of 472.74% was achieved from the combined application of 69 kg N ha^{-1} and 5.6 t ha^{-1} compost (Table 4). The second highest net benefit of birr 27598.65 with acceptable MRR of 107.49% was obtained from the combined application of 46 kg N ha^{-1} and 5.6 t ha^{-1} compost. Since the minimum acceptable rate of return assumed in this experiment was 100%, the treatments with application of 23 kg N ha^{-1} without compost, 46 kg N ha^{-1} without compost, 5.6 t ha^{-1} compost and 46 kg N ha^{-1}, and 5.6 t ha^{-1} compost and 69 kg N ha^{-1} met the requirement. Nonetheless, the highest MRR was obtained from the application of 23 kg N ha^{-1}. Besides, the results of economic analysis showed that combined application of 5.6 t ha^{-1} compost with 46 kg ha^{-1}, and 69 kg N ha^{-1} were economically an alternative dose. The net benefit increased by birr 7656 and 4337 over the lowest N rate (23 kg N ha^{-1}) owing to the combined application of 5.6 t ha^{-1} compost with 46 kg ha^{-1}, and 69 kg N ha^{-1} respectively.

Application of compost not only increases crop yield through the release of nutrients but also improve the physical, biological and chemical properties of soils. In this study, despite the substantial yield increment due to the application of compost and chemical fertilizers, the highest net benefit was obtained from combined application of 5.6 t compost with 69 kg N ha^{-1}. In addition, treatments above the minimum acceptable marginal rate of return, i.e., either the sole N or combined applications with compost could be recommended as alternative sources for users.

Table 4. Marginal analysis for the combined effects of compost and N fertilizers on wheat grain and straw yields

Treatment		TVC (birr ha^{-1})	Marginal cost (birr ha^{-1})	Net benefits (birr ha^{-1})	Marginal benefit (birr ha^{-1})	MRR%
N rate (kg ha^{-1})	Compost (t ha^{-1})					
0	0	0.00	-	14844	-	-
23	0	745.00	745.00	23261.15	8416.70	1129.76
46	0	1444.00	699.00	26194.25	2933.10	419.61
69	0	2146.00	702.00	26847.65	653.40	93.08
46	5.6	2844.68	698.68	27598.65	751.00	107.49
69	5.6	3546.68	702.00	30917.25	3318.60	472.74

TVC= Total Variable Cost, MRR= Marginal Rate of Return

Conclusion

Applications of inorganic N in combination with compost significantly enhanced grain and biomass yields of wheat compared to either compost or inorganic N fertilizer applied alone. The combined application of 46 kg N and 16.8 t ha^{-1} compost, a highly promising treatment, resulted in grain yield advantages of 140% and 23% over the control and the highest N rate (69 N ha^{-1}), respectively. The lowest grain yield was recorded from the control treatment. Moreover, the grain yield increased with increasing levels of the combined applications of nitrogen and compost up to 16.8 t ha^{-1} compost and 46 kg N ha^{-1}, but decreased at the highest levels of both nutrient sources. The maximum total N uptake was observed from the combination of 46 kg ha^{-1} inorganic N with 16.8 t ha^{-1} compost, followed by 69 kg N ha^{-1} with 11.2 t ha^{-1} compost. Nitrogen apparent recovery and agronomic efficiency were increased in response to applied mineral and organic N rates where the maximum records was observed at the lower rate of N.It was also apparent that more of the nutrients applied were assimilated by the grain than that achieved by the straw. The combined application of 69 kg N ha^{-1} and 5.6 t ha^{-1}compost produced optimum grain yield and realized the maximum net benefit, with the second highest MRR next to 23 kg N ha^{-1} mineral fertilizer. Thus, for improved soil health and sustainability of crop yield, addition of 69 kg N ha^{-1} with 5.6 t ha^{-1} could be suggested for the area. Moreover, further research is needed to generate research recommendations for similar agro-ecologies, soil and crop types.

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