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Evaluation of Synergistic Effect Organic and Inorganic Fertilizing System on Grain Yield of Bread Wheat (*Triticum aestivum* L.) at Southern Tigray, Northern Ethiopia

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Abstract

Study on the integrated effect of organic and chemical fertilizer levels on bread wheat was conducted in 2013 cropping season at high lands of Adi-golo and Mekan districts of Tigray, Ethiopia with the objective of determining the optimum integration of organic and inorganic fertilization for bread wheat production. The field experiment consists four level of N/P_2O_5 (0/0, 23/23, 46/46 and 69/69 kg ha^{-1}) and five level of farmyard manure (0, 4, 6, 8 and 10 t ha^{-1}) arranged in factorial RCBD with three replications. Organic and chemical fertilizer applications had significant ($P<0.05$) effect on grain yield in the sites. Higher grain yield (5.04 and 2.19 t ha^{-1}) with acceptable marginal of rate return (MRR=1228.9 and 2788.9%) were obtained in the combined application of 46/46 N/$P_2 0_5$ kg ha^{-1}+6 t ha^{-1} farmyard manure and 46/46 N/P_2O_5 kg ha^{-1}+10 t ha^{-1} farmyard manure at Adi-golo and Mekan areas respectively. Combined applications of organic and chemical fertilizers are more effective than sole application of organic or chemical fertilizers for sustainable Wheat and soil productivity enhancement.

Keywords: Organic fertilizer; Chemical fertilizer; Wheat; Manure

Introduction

Wheat is one of the most important cereals cultivated in Ethiopia. In area of production, wheat ranks 4th after Teff, Maize and Sorghum and 3rd in total grain production after Maize and Teff and 2nd in yield to Maize. It is cultivated by 4.614 million farmers and accounts for more than 17.9% of the total cereal production [1]. However, the mean national yield is 2.5 t ha^{-1}, which is 13 and 32% far below Africa and world average productivity respectively [2]. The low yield of wheat in Ethiopia is primarily due to depleted soil fertility [3-6], little or no addition of fertilizers [3,7,8], unavailability of other modern crop management inputs [3], soil degradation [9,10], and poor rainfall distribution and wheat diseases [11]. Ethiopia has one of the highest rates of nutrient depletion in sub Saharan Africa. The estimated annual loss of phosphorus and nitrogen resulting from the use of dung and crop residues for fuel is equivalent to the total amount of commercial fertilizer use [12]. Nitrogen and Phosphorus are among the most productivity limiting nutrients [13-15]. Land degradation and nutrient depletion are exacerbated by overgrazing, deforestation, population pressure and the poor land use planning [12].

Therefore managing soil fertility is crucial for improving agricultural productivity Ethiopia. Nevertheless, many farmers refrain from using fertilizer due to escalating costs [16], uncertainty about the economic returns to fertilizing food crops and, more often, lack of knowledge as to which kinds and rates of fertilizers are suitable [17]. The physical application rates of fertilizer are also well-below those recommended and estimated. Only 30-40% of Ethiopian smallholders use fertilizer [18] and the physical application rates of fertilizer are on average only 37-40 kg ha^{-1}.

Application of organic materials alone or in combination with inorganic fertilizer helped in maintenance of soil fertility and crop productivity [19-21]. The positive influence of organic fertilizers on soil fertility, on crop yield and quality has been also indicated in the research finding of [22-24]. Manures contribute to improve water storage, infiltration capacity and reduce erosion and loss of nutrients [25-27].

Though there are not any concurrent studies conducted to evaluate the combined effects of organic and chemical fertilizers in wheat crop production in the study area, research efforts on how to use of farmyard manure together with chemical fertilizers could be one alternative solution for sustainable fertility management and improving wheat yield. Thus, this study was designed to evaluate the effects of different integrated organic and chemical fertilizers on grain yield of bread wheat.

Materials and Methods

The study area

The study was conducted high land areas of ofla (Adigolo, 39.33°E, 12.31°N and having an elevation 2490 m.a.s.l) and Enda Mehoni (Mekan, 39.32°E and 12.44°N and having an elevation 2430 m.a.s.l) districts of southern Tigray, northern Ethiopia in 2013 main cropping season. Rainfall is bimodal, with a short rainy season from February-March (Belg) and the main rainy season from June-September (Kiremt). The rainfall pattern of the study sites is presented in Figures 1 and 2. The major crops grown in the area are Wheat (*Triticum aestivum* L), Barley (*Hordium vulgare*) and Fababean. Mixed crop-livestock farming system is an agricultural production system practiced in the study areas. Both study sites have long cereal based cropping history. The dominant soil type for the study area is vertisols with minimum and maximum air temperature 8 and 22°C respectively.

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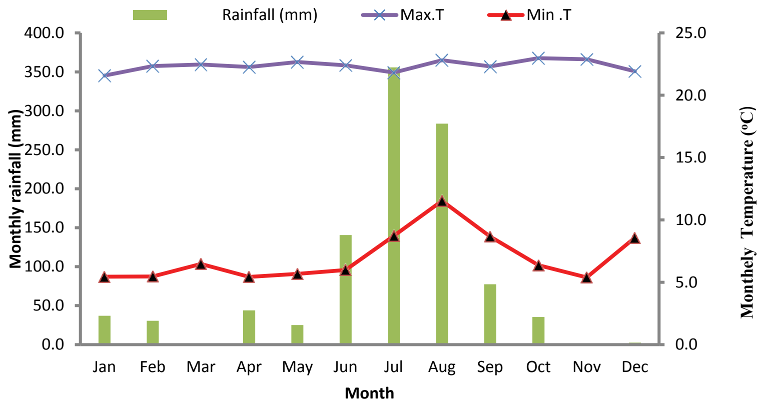

Figure 1: Monthly Rainfall, Average Maximum (Max. T.) and Minimum (Min. T.) Temperature of the Adi-golo in 2013 [28].

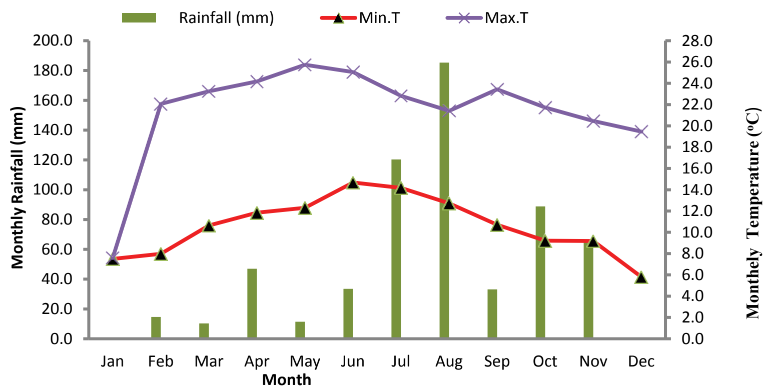

Figure 2: Monthly Rainfall, Average Maximum (Max. T.) and Minimum (Min. T.) Temperature of the Mekan in 2013 [28].

Treatments and experimental design

The Farmyard manure (FYM) used for the experiment was well decomposed and applied all at planting with full dose of Phosphorus fertilizer while, N fertilizer was applied in split form with 1/3rd of the dose applied at planting and the remaining 2/3rd after 40 days of sowing. The source of phosphorus and N fertilizer was triple supper phosphate (46% P_2O_5) and Urea (46% N) respectively. Treatments were laid out in a randomized complete block design with three replications. The treatments consists four level of N/P_20_5 combination (0/0, 23/23, 46/46 and 69/69 kg ha^{-1}) and Five levels of farmyard manure (0, 4, 6, 8 and 10 tone ha^{-1}) and their interactions. The variety used in the experiment was Mekelle3.

Data collected

Soils data collection: ***Soil sampling, sample preparation and analysis:*** Composite surface soil samples were collected using Auger from five to ten spots from each block to form one composite soil sample per block for initial soil fertility evaluation from experimental fields (0-30 cm depth). Similarly, samples were collected after harvest from each plot and then composited by replication to obtain one representative sample per treatment. Particle-size distribution was determined using hydrometer method [28,29]. Soil pH and electrical conductivity (EC) were measured in soil: water extracts (1:2.5) [30]. Organic matter (OM) content was determined by the Walkley and Black method [31]. Total nitrogen (N) was analyzed by Kjeldhal method [32]. Available phosphorus (P) was determined using Olsen method [33]. One molar neutral ammonium acetate (pH=7) was used to extract the exchangeable cations (Ca, Mg, K and Na) [34].

Grain yield (kg $plot^{-1}$): The grain yield was taken from each plot by excluding the border rows and adjusted to 12.5% moisture content and then converted to hectare basis.

Statistical analysis

The Analysis of Variance (ANOVA) on the agronomic traits was computed using the General Linear Model (GLM) procedure of SAS [35] was following the standard procedures of ANOVA for Randomized Complete Block Design (RCBD) [36] for the full set of treatments. The differences among farming practices were considered significant if the P-values were $\leq$ 0.05 and Least Significance Difference (LSD) was used to compare among farming systems. For the on farm trials analysis was done using descriptive analysis.

Partial budget analysis

Grain yield data for the organic and in organic fertilizers effects were subjected to economic analysis, using the CIMMYT [37] partial budget methodology to evaluate the economic profitability of fertilizer and manure options for determination of the economic optimum rate. NP fertilizer rates and manure were analyzed separately by calculating Gross Benefit (GB), Total Costs that Vary (TCV), Net Benefit (NB), and the Marginal Rate of Return (MRR) for each treatment (that is, relative to the next lowest cost or non-dominated treatment for the NP and manure). Dominance analysis was used to screen treatments which have higher variable cost and lower net return and dominated treatment removed from further consideration.

Results and Discussion

Soil physical-chemical properties

According to the soil PH rating established by Tekalign [38] the mean pH values of the composite surface soil samples of the experimental site was categorized under the slightly neutral soil reaction class. The organic matter contents were in the range of 0.68-0.98% on the surface soils (Table 1). These values fall under very low range based on the ratings of soil test values established by Tekalign [38] Total nitrogen levels of the study sites ranges between 0.08 and 0.09% and are taken as very low [39]. It, therefore soils of the study areas are low to very low in their total nitrogen status (Table 1). Moreover, according to Olsen et al. [33] rating, the average available phosphorus contents of the composite surface soil samples of the experimental site fall under the low P status (Table 1). This indicate the low fertility status of the soil aggravated by continuous cereal based cultivation, lack of incorporation of organic materials in to the soils through mulching or crop residues and frequent tillage. Continuous cropping and inadequate replacement of nutrients removed in harvested materials or lose through erosion and leaching has been the major causes of soil fertility decline. The electrical conductivity ranged from 0.01 to 0.21 dSm^{-1} indicating that these soils have a low content of soluble salts and that there is no danger of salinity in the study areas (Table 1).

Grain yield

The statistical analysis revealed significant ($p \leq 0.05$) main and interaction effect of farmyard manure and NP fertilizers on grain yield of bread wheat (Tables 2, 3, 4 and 5). Maximum grain yield was obtained in treatment receiving combined application of 46/46 $kgha^{-1}$ N/P_20_5+6 tone ha^{-1} of farmyard manure for Adi-golo and 46/46 $kgha^{-1}$ N/P_20_5+10 tone ha^{-1} of farmyard manure for Mekan areas respectively; however the lowest grain yield was recorded on plots without any fertilizer application. Hence, this organic and inorganic fertilizing system integration generated 144% and 47% yield increment compared to the control treatment and current NP fertilizer recommendation respectively at Adi-golo. Similarly 162.5% and 12.8% yield increment was obtained from combined application of organic and inorganic fertilizer compared to the control treatment and current NP fertilizer recommendation respectively at Mekan areas. This study strongly confirms the role of manure and chemical fertilizer in increasing grain yield of bread wheat but integration of them has more effect than application of farmyard manure or N/P_20_5 fertilizer alone. In line to this study integrated use of both organic manure and inorganic fertilizer has been emphasized as a rational strategy in improving crop yields [40].

Soil properties	Adi-golo	Mekan
PH $_{water(1:2.5)}$	6.3	7.3
Total N (%)	0.09	0.08
Available P.(mg kg^{-1})	6.1	7.5
OC (%)	0.68	0.98
C/N ratio	7.39	12.25
CE (dsm^{-1})	0.12	0.13
CEC (cmol (+)/kg soil)	46	44
Ca^{2+} (cmol (+)/kg soil)	11.1	9
Na^{+} (cmol (+)/kg soil)	5	5.1
Clay (%)	60	44
Sand (%)	15	31
Silt (%)	25	25
Textural class	clay	clay

Table 1: Soil physico-chemical properties of the study sites.

Source	DF	Mean Square
Location(L)	1	154.428***
Replication	2	0.02933
NP-Fertilizer rate	3	7.92552***
Farmyard manure (FYM)	4	0.66883***
NP-Fertilizer rate x Farmyard manure	12	0.44931***
Location × NP-Fertilizer rate	3	0.39512***
Location × Farmyard manure	4	0.63099***
Location × NP-Fertilizer rate x Farmyard manure	12	0.57831***
Residual	78	0.02012

***=significance at p=0.001, **=significance at p=0.01 and *=significance at p=0.05.

Table 2: Combined mean square values for grain yield of bread wheat.

N/P_2O_5 ($kg\ ha^{-1}$) rate	Grain yield ($t\ ha^{-1}$)	
	Adi-golo	Mekan
0/0	0.83	2.8
23/23	1.15	3.59
46/46	1.68	4.13
69/69	1.76	3.99
LSD	0.073	
Farmyard manure ($t\ ha^{-1}$) rate		
0	1.27	3.22
4	1.54	3.71
6	1.46	3.57
8	1.26	3.58
10	1.25	4.05
LSD	0.115	
Location	1.356	3.63
LSD	0.052	
CV	5.69	

Table 3: Effect of main factor treatments on grain yield.

Farmyard manure ($t\ ha^{-1}$)	N/P_2O_5 ($kg\ ha^{-1}$)			
	0/0	23/23	46/46	69/69
0	1.34	1.94	2.98	2.71
4	1.96	2.59	2.77	3.18
6	1.65	2.43	2.75	3.25
8	2.01	2.20	2.77	2.69
10	2.11	2.67	3.27	2.56
				NP × FYM LSD 0.163 CV(%) 5.7

Where: FYM=Farmyard manure, NP= N/P_2O_5

Table 4: Interaction effect of organic and inorganic fertilizer level on grain yield of bread wheat.

Marginal Rate of Return (MRR) analysis was done for the 20 treatments combinations under varying costs and prices (Tables 6). In economic analysis, it is assumed that farmers require a minimal rate of return of 100%, representing an increase in net return of at least 1 Birr for every 1 Birr invested, to be sufficiently motivated to adopt a new agricultural technology [38]. The results of the partial budget analysis showed maximum net benefit of 24,841 Birr ha^{-1} with an acceptable Marginal Rate of Return of 1228.9% was recorded from the integrated application of 46 kg N ha^{-1}, 46 kg P_20_5 ha^{-1} and 6 tone FYM ha^{-1} at Adi-golo and 60,991 Birr ha^{-1} with an acceptable MRR of 2788.9% from the integrated application of 46 kg N ha^{-1}, 46 kg P_20_5 ha^{-1} and 10 tone FYM

Farmyard manure ($t\ ha^{-1}$)	Adi-golo N/P_2O_5 ($kg\ ha^{-1}$)				Mekan N/P_2o_5 ($kg\ ha^{-1}$)			
	0/0	23/23	46/46	69/69	0/0	23/23	46/46	69/69
0	0.75	1.02	1.49	1.81	1.92	2.86	4.47	3.61
4	0.9	1.29	1.73	2.24	3.03	3.89	3.80	4.11
6	0.89	0.92	2.19	1.85	2.42	3.93	3.31	4.64
8	0.87	1.11	1.50	1.57	3.16	3.30	4.04	3.81
10	0.77	1.4	1.50	1.34	3.45	3.94	5.04	3.77
				NP × FYM × L LSD 0.23 CV(%) 5.7				

Where: FYM=Farmyard manure, NP=N/P_2o_5 and L=location.

Table 5: Interaction effect of organic and inorganic fertilizer level on grain yield of bread wheat.

N	P_20_5	FYM	Adi-golo				Mekan			
			GY	TVC	NB	MRR (%)	GY	TVC	NB	MRR
($kg\ ha^{-1}$)	($kg\ ha^{-1}$)	($t\ ha^{-1}$)	($t\ ha^{-1}$)	(Birr/ha)	(Birr/ha)		($t\ ha^{-1}$)	(Birr/ha)	(Birr/ha)	(%)
0	0	0	0.75	0	9789	0	1.92	0	16809	0.0
0	0	4	0.9	900	10761	216	3.03	900	38529	4826.7
0	0	6	0.89	1350	10220		2.42	1350	30071	
0	0	8	0.87	1800	9471		3.16	1800	39241	2037.8
0	0	10	0.77	2250	11010		3.45	2250	42639	
23	23	0	1.02	1139.5	8831.5		2.86	1139.5	36079.5	
23	23	4	1.29	2039.5	14691.5	1302.2	3.89	2039.5	48569.5	2775.6
23	23	6	0.92	2489.5	9431.5		3.93	2489.5	48639.5	15.6
23	23	8	1.11	2939.5	11399.5	437.3	3.30	2939.5	39960.5	
23	23	10	1.4	3389.5	14849.5		3.94	3389.5	47791.5	
46	46	0	1.49	2279	17130	253.4	4.47	2279	55792	888.9
46	46	4	1.73	3179	19311	484.7	3.80	3179	46221	
46	46	6	2.19	3629	24841	1228.9	3.31	3629	37100	
46	46	8	1.50	4079	15421		4.04	4079	48441	2520.2
46	46	10	1.50	4529	14841	14806.7	5.04	4529	60991	2788.9
69	69	0	1.81	3418.5	20111.5	585.6	3.61	3418.5	43511.5	1574.0
69	69	4	2.24	4318.5	24840.5	1050.9	4.11	4318.5	49111.5	622.2
69	69	6	1.85	4768.5	19320.5		4.64	4768.5	55512.5	1422.4
69	69	8	1.57	5218.5	15152.5		3.81	5218.5	44272.5	
69	69	10	1.34	5668.5	11790.5	59.3	3.77	5668.5	43380.5	

Where FYM=Farmyard manure, TVC=Total Variable Cost, NB=Net benefit, MRR=Marginal rate of return

Table 6: Partial budget analysis for NP and Cattle manure fertilizers on grain yield.

ha^{-1} respectively at Mekan areas. But the profitability and feasibility of an integrated crop nutrient system is not determined by its ultimate economic return per hectare at first season but, manure fertilizer had beneficial residual effects on crop production significantly more grain yield obtained from residual of farmyard manure applied due to the slow release of nutrients from FYM in the former cropping season [21].

Conclusion and Recommendation

From this finding the integrated use of farmyard manure, and N and P fertilizers are efficient than the use of either N/P or FYM alone. It can be concluded that use of farmyard manure and chemical fertilizer considerably improve grain yield of Wheat. The result in this investigation showed that use of 46/46 kg ha^{-1} N/P_20_5 chemical fertilizer integrated with 6 t ha^{-1} farmyard manure fertilizer and 46/46 kg ha^{-1} N/P_20_5 chemical fertilizer integrated with 10 t ha^{-1} farmyard manure fertilizers could produce satisfactory yield of Wheat in the study areas of Awligra and Mekan respectively.

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