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Effects of mineral nitrogen and phosphorus fertilizers on yield and nutrient utilization of bread wheat (*Tritcum aestivum*) on the sandy soils of Hawzen District, Northern Ethiopia

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Abstract: On-farm field experiments were conducted to assess the effects of nitrogen (N) and phosphorus (P) on yield, yield components, nutrients uptake and use efficiencies, protein content of bread wheat, residual soil nitrogen and phosphorus availability and economic return of fertilizer application. The locations of the experiments were in two nearby farmers' field at Hawzen district, Northern Ethiopia. Factorial combinations of five N levels (0, 46, 69, 92 and 138 kg N/ha) and four levels of P (0, 46, 69 and 92 kg P_2O_5/ha) were laid out in a randomized complete block design with three replications. Experimental Field 1 was relatively better in its soil fertility than experimental Field 2 especially in its phosphorus availability and cation exchange capacity (CEC). However, both fields were low in their total soil nitrogen content. Grain yield of wheat significantly increased by 46% and 15% in Field 1 and Field 2, respectively at nitrogen application rate of 46 kg N/ha than the control. Nitrogen fertilization increased straw yield significantly only in experimental Field 1. Phosphorus application at a rate of 46 kg P_2O_5/ha increased significantly grain and straw yields by 38 % and 46 %, respectively in Field 2 than control. It is also economical to apply phosphorus at this rate for such farmers' field because the grain yield marginal rate of return was 179 %. Consistent results were observed on wheat nutrient uptakes and nutrient use efficiencies. Grain and straw yields of wheat were not significantly affected by the main effect of phosphorus application in Field 1. These results are consistent with the soil analysis result before planting where the soil phosphorus was found to be low in Field 1 and very low in Field 2. Previous management by the farmers may have influenced the soil fertility status. There were no interaction effects of nitrogen and phosphorus to affect wheat productivity and nutrient utilization in both fields. Future approach to soil fertility management should consider the past management history and should also be site specific based on soil fertility assessment. As a result, a combined application of 46 kg N/ha and 46 kg P_2O_5/ha are recommended to achieve sustainable bread wheat production on the sandy soils of Hawzen district. But in fields with higher initial soil phosphorus level, there is no need of applying phosphate fertilizer.

Keywords: Bread Wheat, Marginal Rate of Return, Nitrogen, Nutrient Use Efficiency, Phosphorus, Protein Content

1. Introduction

Wheat is an important large-acre crop which is grown on more acres globally than any other and provides a major share of the nutritional requirements for the growing world population [1]. It is a staple food for about one third of the world's population [2], being cultivated in Ethiopia on about 1.51 million hectares and delivering about 3.3 million tons of grain yields which makes Ethiopia the largest wheat producer in sub Saharan Africa [3]. Ethiopia is the second largest wheat producer in sub-Saharan Africa, after South Africa [4]. However the Ethiopian government is forced to import wheat every year because of higher demand than supply. Wheat is the single most important staple crop imported from abroad and most of the humanitarian food aid and commercial import takes in the form of wheat [4].To feed the growing human population and fill the yield gaps between wheat consumption and production in Ethiopia, increasing production of wheat is paramount important. Besides wheat straw is an integral component of livestock feed and commonly used as a roof thatching material both in the rural and urban areas in Ethiopia. Increasing wheat production in Ethiopia can be possible by increasing productivity of small holder producers in the mid and highlands and by bringing more area into wheat production in the lowlands. In the mid and highlands, wheat production is constrained by both biotic and abiotic factors such as diseases and pests, poor soil fertility and moisture stress. Poor agronomic and soil management, inadequate level of technology generation and dissemination are the most significant constraints to increased wheat production in the highlands and mid highlands of Ethiopia. Low soil fertility and slow progress in developing wheat cultivars with durable resistance to disease are considered the most important constraints limiting wheat production in Ethiopia [4, 5].

With fertilizers becoming important inputs to maximize crop yields, and nitrogen fertilizer being determinant in wheat production in Ethiopia, several N fertilizer trials have been undertaken to determine the optimum level. Results indicated that N rates had significant positive effect on yield up to 230 kg ha^{-1}[6]. Crop response to nitrogen fertilizer is influenced by factors such as nitrogen fertilizer management, soil type, crop sequence and supply of residual and mineralized nitrogen [7]. A good supply of nitrogen to the plant stimulates root growth and development as well as uptake of other nutrients [8,9]. The total wheat N uptake increased with increasing N application [10]. Nitrogen rate significantly influenced grain yield, protein content, N uptake efficiency, N biomass production efficiency, N utilization efficiency, N use efficiency for grain and N use efficiency for protein yield of wheat [11]. Increasing levels of nitrogen increases grain and dry matter yields, number of kernels per head and plant height of wheat [2, 10, 12). Nitrogen application increased the number of tillers at late tillering stage of crop growth of wheat [10, 13]. Nitrogen nutrition stimulates tillering probably due to its effect on cytokinin synthesis [14]. There are contradictory evidences on the effect of nitrogen on thousands seed weight of wheat. A report by [15] and [10] indicated reduction in thousands grain weight of wheat by N fertilizer application, despite increase in yields. Furthermore, [15] concluded that N fertilizer applied at rates to optimize yield response would not necessarily give a comparable improvement in 1000-grain weight. On the other hand, [2, 16) indicated nitrogen application increased thousands seed weight of wheat. Adequate nitrogen supply improves protein content of vegetative organs as well as storage tissues [17] and manufactures protein from carbohydrates [18]. Nitrogen fertilization increased protein content of wheat and the highest grain protein content (13.09%) was obtained at N rate of 120 kg N/ha [16]. A report from [10] indicated residual soil total N tended to remain almost the same irrespective of different levels of N applications.

Phosphorus is the second most essential element of crop production and it is deficient in most soils around the world to achieve maximum yields [9]. Adequate phosphorus enhances many aspects of plant physiology like fundamental process of photosynthesis, flowering, seed formation and maturation [9, 19]. Fertilizer P application significantly and positively influenced grain yield and number of tiller of wheat [10]. A report of [17] indicated that cereal crops requires about 20 kg P/ha for normal production. Moreover, residual soil available P content increased with increasing rates of applied P up to 20 kg P/ha after sowing [10].

Nitrogen and phosphorus are considered as the most deficient nutrients in soils of Ethiopia including Hawzen [20, 21]. This indicates that nitrogen and phosphorus are the most yield limiting factors of cereals including wheat production in Ethiopia. Soil fertility status also varies within adjacent farms or plots mainly due to preceding individual farmer's soil management practices. Though there were information on the effects of nitrogen and phosphorus on wheat productivity in Ethiopia, a comprehensive work is scanty in sandy and degraded soils like the case of Hawzen. This study investigates effects of N and P fertilizers and their factorial combinations on wheat production based on indicative parameters.

2. Materials and Methods

2.1. Area Description

On-farm field experiments were conducted in 2013 growing season at Hawzen district, Northern Ethiopia in two nearby farmers' fields represented as Field 1 and Field 2 (located at 39° 27' 2" E and 13° 15' 16" N, altitude of 2263 meter above sea level for Field 1 and at 39° 27' 30" E and 13° 59' 9" N, altitude of 2275 meter above sea level for Field 2). Hawzen district is located in tepid to cool sub moist mountains plateau agro-ecological zone [22]. Soils in Hawzen district are one of the most degraded soils in the Tigray region (Northern Ethiopia) which are believed to be very poor in soil organic matter. Wheat is grown during the main season from June to September (Figure 1). The wheat growing season of 2013 had relatively enough rainfall compared to the long term average. Annual mean maximum temperature is 24^{o}C and mean minimum is 7.7 ^{O}C. The rainfall data for the district was summarized from the nearest district data of Hawzen Office of Agriculture and Rural Development [23]. Temperature and potential evapo-transpiration data were estimated using the LocClim 1.0 software [24].

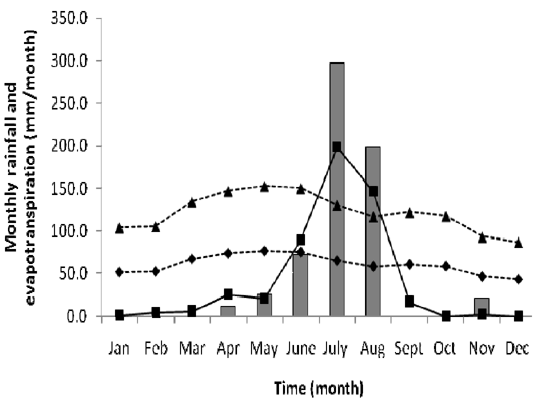

Figure 1. *Average monthly rainfall (solid line and squares), actual monthly rainfall in 2013 (bars) and estimated potential evapo-transpiration (dashed line and triangles) and estimated half potential evapo-transpiration (dashed line and diamonds).*

2.2. Experimental Design and Procedures

The treatments were five levels of nitrogen (0, 46, 69, 92 and 138 N kg/ha) and four levels of phosphorus (0, 46, 69 and 92 P_2O_5 kg/ha). The treatments were replicated three times in a Randomized Complete Block Design in a plot size of 3 m by 4 m. Nitrogen and phosphorus were applied in the form of urea and Triple Super Phosphate (TSP), respectively. Phosphorus and half of the nitrogen rates were incorporated into the soil at planting. The remaining half of the nitrogen rates were applied during tillering.

The initial experimental fields' soils were analyzed for texture, organic carbon, total nitrogen, Cation Exchange Capacity (CEC), available P, exchangeable Ca and Mg, and pH. Soil samples at flowering and after harvest were also analyzed for total nitrogen and available phosphorus. The methods used for physico-chemical analysis were: pH [25], organic carbon (modified Walkley and Black method [25]), texture (hydrometer method procedure of Bouyoucos [26]) available phosphorus [27], total nitrogen [Kjeldehal method [28], CEC and exchangeable Ca and Mg (Neutral ammonium acetate method [29]). Grain and straw samples were analyzed for nitrogen and phosphorus. Plant total nitrogen was analyzed using (Kjeldehal method [28]) and phosphorus using (dry ashing).

The bread wheat variety used in this experiment was Pica flor (*kakaba*) planted on 10 July 2013 for Field 1 and 11 July 2013 for Field 2. Harvesting was conducted on 30 October for Field 1 and 23 October for Field 2. Data on number of plant height and spike length were taken at maturity. Above ground biomass from sample quadrants were sun-air dried before weighing. The spikes were threshed and cleaned and grain yield was weighed. The straw yield was calculated by subtracting grain yield from the above ground biomass. Grain and straw yields were adjusted to 12.5 % moisture content.

Nutrient recovery and uptake, agronomic and physiological nutrient use efficiency were calculated from establised formulas and facts as follows:

1. The total uptake of nitrogen or phosphorus were calculated by multiplying the grain and straw yield (kg/ha) with the nitrogen or phosphorus concentration in (%) of each treatment as follows:

   a) N or P uptake of grain or straw (kg/ha)
   = Yield of grain or straw (kg/ha) x nutrient concentration of grain or straw (%) x 10^{-2} Eq [1]
   b) Total N or P uptake = N or P uptake of grain + N or P uptake of straw Eq [2]

2. The efficiency of N or P applied in the different treatments was estimated by calculating the N or P recovered in the above ground biomass of wheat (straw and grain) from the N or P applied in the treatments using the formula described by [30]
   Apparent N or P recovery (%) =
   (N or P uptake of treatment in kg/ha – N or P uptake of control in kg/ha) x 100 /(N or P added in kg/ha) Eq [3]

3. Agronomic and physiological N or P use efficiencies were calculated using the formula described by [31].
   a) Agronomic N or P Use Efficiency = (Grain yield of treatment – Grain yield of control) /(N or P added in kg/ha) Eq [4]

   b) Physiological N or P Use efficiency = (Grain yield of treatment – Grain yield of control)/(N or P uptake of treatment – N or P uptake of control) Eq [5]
   Where yield and N or P added and uptakes were in kg/ha

4. Grain protein content was calculated as % protein content = % N grain content × 5.7 Eq [6] [32].

2.3. Data Analysis

Generated data were subjected to analysis of variance. All analysis were performed with GenStat 12^{th} edition statistical software package (VSN international).

3. Results and Discussion

3.1. Soil Properties before Planting

The chemical and physical properties of the soils of the experimental fields are indicated in Table 1. The soil pH for Field 1 is neutral and Field 2 is slightly acidic. Both fields are very low in organic carbon content (<2 %), medium in CEC (in between 13-25 meq/100 g soil), low in total nitrogen (in between 0.05-0.125 %), very low in exchangeable calcium (<2 cmol(+)/kg soil), high in exchangeable magnesium (>3 cmol (+)/kg soil) and low in available phosphorus (< 10 mg/kg soil) in Field 1 and very low (<5 mg/kg soil) in Field 2 [33]. The soil textural classes for both experimental fields are sandy loam. From the results of the soil analysis it can be depicted both nitrogen and phosphorus may be yield limiting for wheat production in the area. Experimental Field 2 was relatively low in its soil fertility than experimental Field 1 especially in its phosphorus availability and CEC.

Table 1. *Surface (0-20 cm) soil properties of experimental fields*

Soil properties	Field 1	Field 2
pH_{water}(1:2.5)	6.83	5.94
Organic carbon (%)	0.67	0.61
P-Olsen (mg kg^{-1})	9.48	4.45
Total-N (%)	0.098	0.102
CEC (meq/100 g soil)	20.4	14.16
Exchangeable Ca (cmol(+)/kg soil)	1.2	1.4
Exchangeable Mg (cmol(+)/kg soil)	4.8	5.2
Clay (%)	14	14
Silt (%)	17	7
Sand (%)	69	79

3.2. Yield Components

Number of effective tillers per plant of wheat significantly increased due to the main effect of nitrogen ($P < 0.001$) and phosphorus ($P = 0.038$) fertilizers application in experimental Field 1 (Table 2). Phosphorus application increased significantly number of effective tillers per plant in Field 2. However, nitrogen fertilization had no significant effect on number of tillers per plant in Field 2. These results are supported by the findings of [13] and [10]. Plant height and head length were significantly increased due to main effect of nitrogen and phosphorus fertilization in both fields (Table 2). A report of [2] also shows nitrogen fertilization improved plant height of wheat. A significant decrease in thousands seed weight of wheat was observed due to nitrogen application. The current result is supported by [15] and [10] findings. However, the trend was not observed due to phosphorus application and thousands seed weight of wheat was not significantly affected by phosphorus application. All the measured yield components were not affected significantly by the interaction effect of nitrogen and phosphorus fertilization (Table 2).

3.3. Grain and Straw Yields

Grain yield of wheat significantly increased due to the main effect of nitrogen fertilization in both the experimental fields (Table 3). The result is supported by [6, 12]. Highest grain yields were obtained at the highest nitrogen rate of 138 kg N/ha in both fields but was not statistically different than the rate of 69 kg N/ha in Field 1 and 46 Kg N/ha in Field 2. Straw yield of wheat significantly increased due to nitrogen fertilization in Field 1. The highest straw yield was recorded at the highest nitrogen rate though it was not statistically different than the rate 69 kg N/ha. Straw yield was not affected significantly due to main effect of nitrogen in Field 2. This reveals that nitrogen is more yield limiting factor in Field 1 than Field 2 as both grain and straw yields of wheat responded to nitrogen application while only grain yield of wheat responded to nitrogen in Field 2.

Grain and straw yields of wheat were significantly increased due to the main effect of phosphorus fertilization in Field 2 (Table 3). Highest grain yield was obtained at a rate of 69 kg P_2O_5/ha though it was not statistically different than the preceding lower rate (46 kg P_2O_5/ha).This is supported by [17]. Highest straw yield was obtained at the highest phosphorus rate (92 kg P_2O_5/ha) though it was not statistically different than the preceding lower rate (69 kg P_2O_5/ha). Grain and straw yields of wheat were not significantly affected by the main effect of phosphorus in Field 1. Though it was not statistically significant, 8% grain yield and 11% straw yield increase were observed in Field 1 at the lowest phosphorus fertilization rate (46 kg P_2O_5/ha). The results indicated that phosphorus is yield limiting factor of wheat in Field 2 but not in Field 1. This is supported by the soil analysis result prior to planting where the available soil phosphorus content in Field 2 is very low while the available soil phosphorus in Field 1 is low in its class but near the range of sufficiency of phosphorus in soil (> 10 mg/kg) (Table 1).

Grain and straw yields of wheat were not affected significantly due to the interaction effect of nitrogen and phosphorus fertilization in both experimental fields (Table 3). Earlier works also indicated non-significant interaction effect of nitrogen and phosphorus on wheat yield [10].

Average grain and straw yields of wheat were better in Field 1 than Field 2 indicating a better soil fertility status of Field 1 than Field 2 (Table1).

3.4. Nutrient Uptakes and Recoveries

Total nitrogen and phosphorus uptakes of wheat increased with an increasing rate of nitrogen and phosphorus, respectively in Field 1 (Figure 2). In Field 2 a trend of increase in nitrogen and phosphorus uptakes were observed till a rate of 69 kg N/ha and 69 kg P_2O_5/ha, respectively. However, a trend of decrease in both nutrients uptake were observed in the higher application rates of each nutrients.

Highest recovery fraction of nitrogen was obtained at a rate of 69 kg N/ha in both the experimental fields (Figure 3). Nitrogen recovery was higher in Field 1 than Field 2. Indicating nitrogen is yield limiting factor of wheat in Field 1.This is supported by yield response of wheat (Table 3). Highest recovery fraction of phosphorus was obtained at the highest rate of phosphorus (92 kg P_2O_5/ha) in Field 1 and at a rate of 46 kg P_2O_5/ha in Field 2. Highest recovery fraction at the highest phosphorus application rate in Field 1 is an indication that phosphorus is not yield limiting factor of wheat. Phosphorus recovery was higher in Field 2 than Field 1. Indicating phosphorus is yield limiting factor of wheat in Field 2. These are consistent with the soil phosphorus content and the yield response of wheat to phosphorus application (Table 1 and Table 3).

***Table 2.** Effect of N and P fertilizers on some agronomic parameters of wheat.*

	Field 1				Field 2			
	NETPP	**PH (cm)**	**HL(cm)**	**TSW (gm)**	**NETPP**	**PH (cm)**	**HL (cm)**	**TSW (gm)**
N rate (kg/ha)								
0	2.10	67.37	6.18	40.03	3.32	68.67	6.12	32.39
46	3.10	75.98	6.97	38.87	3.53	69.85	6.67	31.35
69	3.24	76.97	7.30	38.14	2.60	70.58	7.08	28.53
92	3.14	79.12	7.13	37.87	3.70	71.92	6.77	30.12
138	3.91	79.82	7.50	34.73	3.78	70.32	6.97	29.05
LSD	0.64	4.28	0.377	3.5	NS	2.038	0.34	1.88
P-value	<0.001	<0.001	<0.001	0.05	NS	0.042	<0.001	<0.001
P rate (kg P_2O_5/ha)								
0	2.63	73.07	7.00	38.43	2.34	60.84	5.77	31.36
46	3.09	74.96	6.60	38.32	3.57	73.04	7.07	29.94
69	3.48	77.49	7.25	37.74	3.96	74.56	6.92	30.45
92	3.21	77.88	7.20	37.19	3.68	72.64	7.12	29.40
LSD	0.57	3.8	0.337	3.13	0.78	1.823	0.305	NS
P-value	0.038	0.05	0.002	NS	<0.001	<0.001	<0.001	NS
N*P interaction	NS	NS	NS	NS	NS	NS	NS	NS
CV (%)	25	6.8	6.5	11	31	3.1	7.5	7.5

LSD: Least Significant Difference, P-value: Probability value, CV: Coefficient of Variation, NETPP: number of effective tillers per plant, PH: plant height, HL: head length and TSW: thousands seed weight

***Table 3.** Effect of N and P fertilizers on grain and straw yields of wheat*

	Grain yield (kg/ha)		Straw yield (kg/ha)	
	Field 1	**Field 2**	**Field 1**	**Field 2**
N rate (kg/ha)				
0	2496	2309	5715	5239
46	3656	2662	6623	5499
69	4131	2447	7244	6243
92	4398	2663	7592	5804
138	4443	2914	7897	6256
LSD	577	408	966	NS
P-value	<0.001	0.048	<0.001	NS
P rate (kg P_2O_5/ha)				
0	3551	1922	6357	4044
46	3837	2647	7056	5918
69	3988	2997	7044	6444
92	3922	2828	7285	6827
LSD	NS	402	NS	837
P-value	NS	<0.001	NS	<0.001
N*P interaction	NS	NS	NS	NS
CV (%)	18.2	19	16.7	19.5

LSD: Least Significant Difference, P-value: Probability value, CV: Coefficient of Variation

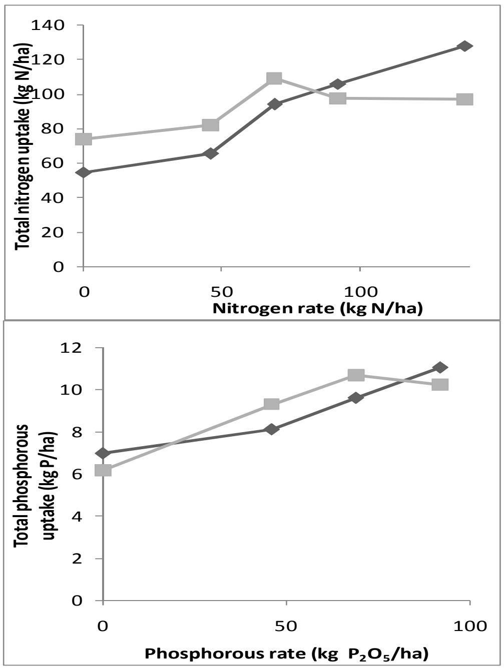

Figure 2. *Nitrogen and phosphorus uptake as influenced by nitrogen and phosphorus application for Field 1 (a line and a triangles) and for Field 2 (a line and squares).*

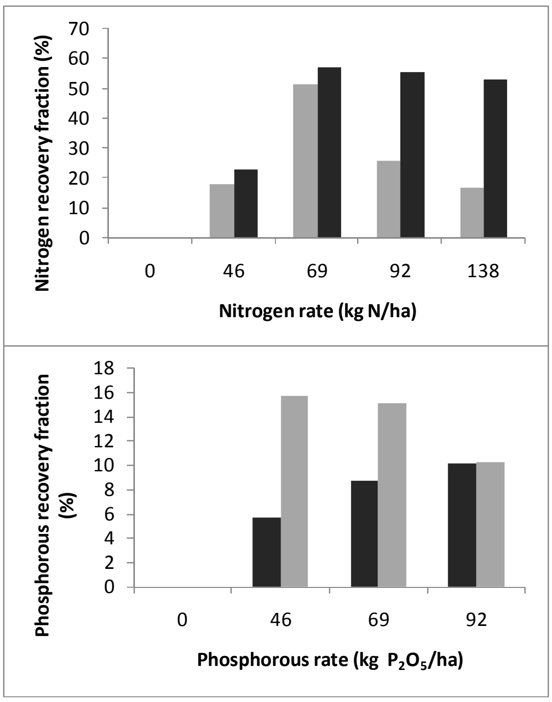

Figure 3. *Nitrogen and phosphorus recovery fractions for Field 1 (black bars) and for Field 2 (grey bars).*

3.5. Agronomic and Physiological Nutrient Use Efficiency

Highest agronomic use efficiency (AUE) of nitrogen was obtained at a rate of 46 kg N/ha in both the experimental fields (Figure 4). AUE of nitrogen was higher in Field 1 than Field 2. AUE of phosphorus was higher in Field 2 than Field 1 and the highest efficiencies were obtained at a rate of 46 kg P_2O_5/ha. The AUE of N and P showed a decreasing trend in both fields except at 69 kg N/ha for Field 2. The results on both N and P agronomic efficiency are supported by the effects of N or P fertilization on yields, nutrient recovery and the soil analysis result before planting (Table 1, Table 3 and Figure 3).

Physiological use efficiencies (PUE) of nitrogen in wheat were higher in Field 1 than Field 2 except at the highest nitrogen rate where both fields attained the same PUE (Figure 5). Highest PUE (109 kg grain yield/kg N total uptake) was attained at 46 kg N/ha in Field 1. However the highest PUE for Field 2 was 42 kg grain yield/kg N total uptake at the highest N level. Indicating nitrogen is more yields limiting in Field 1 than Field 2. Highest PUE of phosphorus (253 kg grain/kg P total uptake) was attained at 46 kg P_2O_5/ha in Field 1 with a decreasing trend in the higher phosphorus application rates (Figure 5). A comparable PUE ranged 222 to 237 kg grain/kg P total uptake were obtained in all the three phosphorus application rates in Field 2.

3.6. Grain Protein Content due to Nitrogen Fertilization

Grain protein contents of wheat were highest at 138 kg N/ha (11.9 %) and 69 kg N/ha (13.36%) application rates for Field 1 and Field 2, respectively indicating the required amount of nitrogen fertilizer to attain the higehst protein content was less in Field 2 than Field 1 (Figure 6). The result is consistent with the trend of nitrogen uptake (Figure 2). A report by [16] also indicated nitrogen fertilization increased protein content of wheat and the highest grain protein content (13.09%) was obtained at N rate of 120 kg N/ha. The lowest grain protein contents were recorded at nitrogen application rate of 46 kg N/ha (6.2%) and the control (9.5%) for Field 1 and Field 2, respectively. These showed the increases in yield of wheat (Table 3) due to nitrogen fertilization at a rate of 46 kg N/ha were attained decreasing the grain protein content of wheat in Field 1 and increasing the protein content of wheat in Field 2.These could be due to dilution effect because Field 1 was more responsive to nitrogen fertilzation than Field 2 and the percent change of increase in wheat grain yield from the control was higher in Field 1 than Field 2 at this rate (Table 3). This indicates the target of wheat nitrogen fertilization in highly responsive soil should not be yield only but it should put into account grain protein content. Because wheat provides more protein than any other cereal crops globally [16]

3.7. Soil Nitrogen and Phosporous Availabilty due to Nitrogen and Phosporus Fertilization

Residual soil total nitrogen content didn't show a trend either due to phosphorus and nitrogen fertilization (data not shown). A report of [10] also shows residual total N tended to remain almost the same irrespective of different levels of applications. However residual soil phosphorus availability showed a trend of increase starting at a rate of 69 kg N/ha in Field 1 and a decrease at the same rate in Field 2 due to nitrogen fertilization both at heading and at harvest (Figure 7). This might be pH difference of the fields (Table 1).

Phosphorus could be fixed in Field 2 and becomes available in Field 1 due to acidifing effect of the nitrogen.

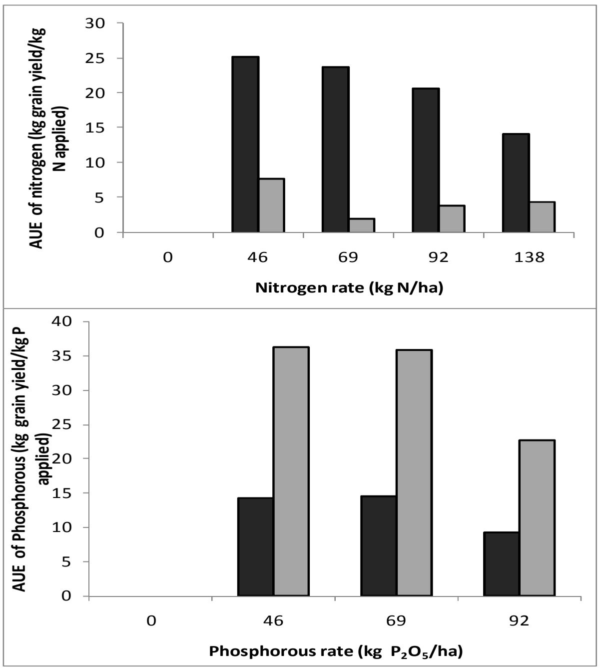

Figure 4. Agronomic use efficiencies of nitrogen and phosphorus for Field 1 (black bars) and for Field 2 (grey bars).

An increasing trends of residual soil phosphorus availability were observed with an increasing application of phosphorus fertilizer rates at flowering in both fields and at harvest in Field 1(Figure 8).The incremental trend was observed up to 69 kg P_2O_5/ha at flowering in Field 2. A report of [10] also indicated that the soil available P content increased with increasing rates of applied P up to 20 kg P/ha after sowing.

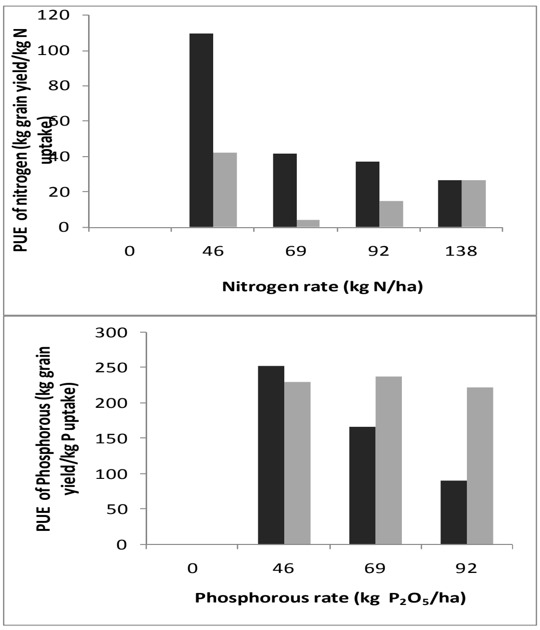

Figure 5. Physiological use efficiencies of nitrogen and phosphorus for Field 1 (black bars) and for Field 2 (grey bars).

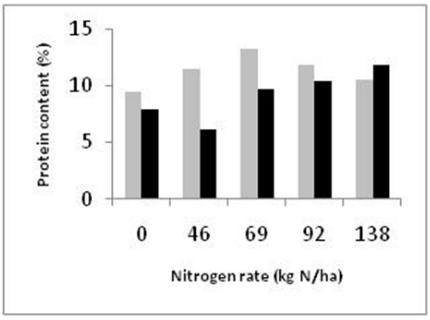

Figure 6. Grain protein content of wheat as influenced by nitrogen ferilization for field1 (black bars) and for field2 (grey bars).

3.8. Partial Budget Analysis

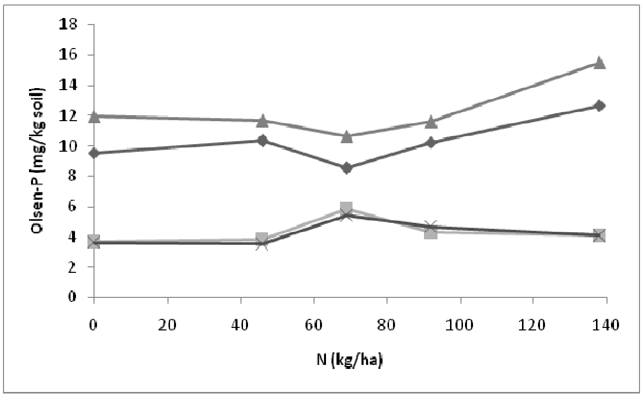

Figure 7. Soil P availability collected at two growth stages as influenced by N fertilization triangles and a line Field 1 at harvest, diamonds and a line Field 1 at flowering, rectangles and a line Field 2 at flowering, and crosses and a line Field 2 at harvest

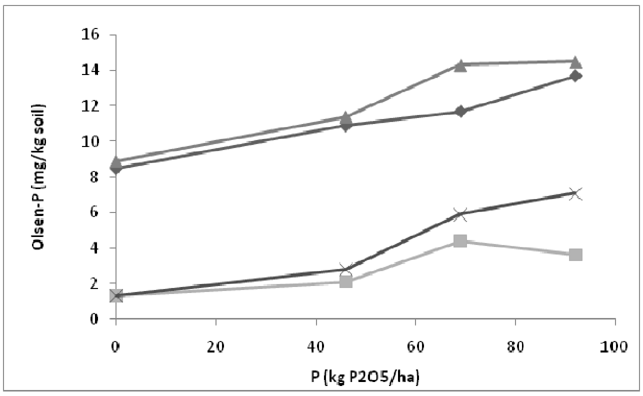

Figure 8. Soil P availability collected at two growth stages as influenced by P fertilization triangles and a line Field 1 at harvest, diamonds and a line Field 1 at flowering, rectangles and a line Field 2 at flowering, and crosses and a line Field 2 at harvest

An increase in output will always rise profit as long as the marginal rate of return is higher than the minimum rate of return i.e. 50 to 100% [34]. Data in Table 4 shows that the marginal rate of return at the nitrogen application rates of 46, 69 and 92 kg N/ha were greater than 100% in Field 1 showing that it is economical to apply up to 92 kg N/ha. But Field 2 showed an economically feasible application rate at 46 kg N/ha since it has greater than 50% marginal rate of return. The other treatments were eliminated by the concept of dominance analysis [34] since the net benefit incurred decreased as the cost increased. Wheat straw yield is also important as of grain yield to the small holder farmers because wheat straw is an integral livestock feed. Considering straw in the partial analysis would improve the economic return of nitrogen fertilization in both fields.

Since the marginal rate of return in Field 1 due to phosphorus application is less than 50 to 100%, application of phosphate fertilizer is not economical (Table 5). This is in line with the initial soil P availability (Table 1). But in Field 2, it is economically profitable to apply up to 69 kg P_2O_5/ha. Considering straw yield in the partial analysis would also improve the economic return of phosphorus fertilization in Field 2.

Table 4. *Partial budget analysis of bread wheat produces by applying nitrogen fertilizer*

Fertilizer Rate (kg N/ha	Fertilizer Cost (Birr)	Fertilizer Application & Transport Cost [Birr]	Total Variable Cost (TVC) [Birr]	Grain Yield (kg/ha)	Total Revenue (TR) [Grain yield*11]	Net Revenue [TR-TVC]	Marginal Rate of Return (ratio)	Marginal Rate of Return (%)
				Field 1				
0	0	0	0	2496	17971.2	17971.2		
							4.59	459
46	1252	240	1492	3656	26323.2	24831.2		
							3.98	398
69	1878	300	2178	4131	29743.2	27565.2		
							1.8	180
92	2504	360	2864	4398	31665.6	28801.6		
				Field 2				
0	0	0	0	2309	16624.8	16624.8		
							0.70	
46	1252	240	1492	2662	19166.4	17674.4		

Table 5. *Partial budget analysis of bread wheat produce by applying phosphate fertilizer*

Fertilizer Rate (kg P_2O_5/ha	Fertilizer Cost (Birr)	Fertilizer Application & Transport Cost [Birr]	Total Variable Cost (TVC) [Birr]	Grain Yield (kg/ha)	Total Revenue (TR) [Grain yield*11]	Net Revenue [TR-TVC]	Marginal Rate of Return (ratio)	Marginal Rate of Return (%)
				Field 1				
0	0	0	0	3551	25567.2	25567.2		
							0.10	100
46	1626	240	1866	3837	27626.4	25760.4		
							0.24	24
69	2439	300	2739	3988	28713.6	25974.6		
				Field 2				
0	0	0	0	1922	13838.4	13838.4		
							1.79	179
46	1626	240	1866	2647	19058.4	17192.4		
							1.88	188
69	2439	300	2739	2997	21578.4	18839.4		

4. Conclusions

Nitrogen and phosphorus are known as the most yield limiting nutrients constraining cereal productivity including wheat in Ethiopia. Though there were some evidences on the effects of nitrogen and phosphorus on wheat productivity, a comprehensive work is scanty in sandy and degraded soil like the case of Hawzen. The results of this experiment indicated increase in wheat grain and straw yields, nutrient uptakes, nutrient recoveries, agronomic and physiological use efficiencies with mineral nitrogen and phosphorus fertilization. Even though the experimental fields were near to each other, wheat responses varied to the different nutrients differently. Biologically a combined application (46 to 138 kg N/ha and 46 kg P_2O_5/ha) of NP fertilizers are required. But in fields with higher initial soil phosphorus level like Field 1, there is no need of applying phosphate fertilizer. The economic analysis also supports this since the marginal rate of return in Field 1 due to phosphorus application is less than 50 to 100% indicating application of phosphate fertilizer is not economical. This indicates phosphorus fertilization should follow a soil test based approach to get an economical yield. Generally it can be concluded that a combined application of 46 kg N/ha and 46 kg P_2O_5/ha are recommended to achieve sustainable bread wheat production on the sandy soils of Hawzen district.

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References

[1] Y. Shapiro. Monsanto's plan and prospects for wheat improvement through breeding and biotechnology. In: Reynolds M. and Eaton D., eds. Book of Abstract. Complementary strategies to raise wheat yield potential. Workshop held at CIMMYT, E. Baton, Mexico, DF., CIMMYT. 2009.

[2] M. I. Hussain. and S. H. Shah. Growth, yield and quality response of three wheat (*Triticum aestivum L.*) varieties to different levels of N, P and K. *Int. J. of Agri. and Bio*., 4(3): 362-364. 2002.

[3] Ethiopian Central Statistical Agency (CSA). The Federal Democratic Republic of Ethiopia Central Statistical Agency. Agricultural sample survey, report on area and production of major crops, Addis Ababa, Ethiopia. 2013.

[4] Demeke. M. and F. Di Marcantonio. Analysis of incentives and disincentives for wheat in Ethiopia. Technical notes series, MAFAP, FAO, Rome. 2013.

[5] Teklu. E. and Hailemariam. T. Agronomic and Economic Efficiency of Manure and Urea Fertilizers Use on Vertisols in Ethiopian Highlands. *Agricultural Science in China*. 8(3): 352-360. 2009.

[6] Debreziet Agricultural Research Center (DZARC). Annual Research Report of 1989.DZARC, Debre-Zeit, Ethiopia. Pp. 64- 69. 1989.

[7] J. A. Lory. G. W. Randall. and M. P. Russelle. A classification system for Factors affecting crop response to nitrogen fertilization. *Agron. J.* 87: 869-76. 1995.

[8] Food and Agricultural Organization (FAO). Fertilizers and their use 4th ed. International fertilizer industry association, FAO, Rome, Italy. 2000.

[9] N. C. Brady. and Weil, R.R. The Nature and Properties of Soils (13th ed.). Pearson Education Ltd., USA. 2002.

[10] Damene. D. D. Yield response of bread wheat (*Triticum aestivum* L.) to applied levels of N and P fertilizers on Nitosol of Dawro Zone, South Western Ethiopia, a thesis (M.Sc.), The School of Graduate Studies, Alemaya University, Ethiopia. 2003.

[11] Haile. D. Nigussie. D. and Ayana. A. Nitrogen use efficiency of bread wheat: Effects of nitrogen rate and time of application. *J. Soil Sci. and Plant Nutr.* 12 (3): 389-409. 2012.

[12] Minale. L. Alemayehu A. Tilahun. T. and Abreham. M. Response of Bread Wheat to Nitrogen and Phosphorus Fertilizers at Different Agroecologies of Northwestern Ethiopia. In: M.G. Kinyua. J. Kamwaga. J.O. Owuoche. A. C. Ndiema. P.N. Njau. D. K. Friesen. D. Ouya. (Eds). Proceedings of the 12th Regional Wheat Workshop for Eastern, Central, and Southern Africa. Nakuru, Kenya, 22–26 November 2004. Mexico, D.F.; CIMMYT and KARI. 2006.

[13] M. Tahir. Ali. M. Anjum. S. Iqbal. and M.Yamin. Evaluation of the Effect of Use of N.P. Fertilizer in Different Ratios on the Yield of Wheat (*Triticum aestivum*) Crop. *Pak. J. Life Soc. Sci*. 2(2): 145-147. 2004.

[14] M. A. Botella. A. C. Cerda. and S. H. Lips. Dry matter production, yield and allocation of carbon-14 assimilate by wheat as affected by nitrogen source and salinity. *Agron. J.* 85 (5): 1044 – 1049. 1993.

[15] M. J. Gooding. and W. P. Davies. Wheat Production and Utilization, Systems, Quality, and Environment. CAB International, USA. 1997.

[16] H. Iqtidar. A. K. Muhammad, and A. K. Ejaz. Bread wheat varieties as influenced by different nitrogen levels. *J. Zhejiang Univ Sci.* 7(1): 70-78. 2006.

[17] K. Mengel. and E. A. Kirkby. Principles of Plant Nutrition. Panimo Publishing Corporation, New Delhi, India. 1996.

[18] S. L. Tisdale. W. L. Nelson. J. D. Beaton. and J. L. Havlin. Soil Fertility and Fertilizers (5th ed.). Macmillan Publishing Company, USA. 1993.

[19] F. N. Salisbury. and C. W. Ross. Plant Physiology. 4th ed. Wads Worth Publishing Company, Belmant, California.1992.

[20] Asnakew. W. Tarekegn. M. Mengesha. B. and Tefera. A. Soil fertility management studies and wheat in Ethiopia. In: Hailu. G. D. G. Tanner and Mengistu H. (eds.). Wheat Research in Ethiopia. A Historical Perspective.IAR, CIMMYT, Addis Ababa, Ethiopia. Pp 112-144.1991.

[21] Bereket H. and Yirgalem W. Status Survey of Total Plant and Total and DTPA Extractable Soil Copper, Zinc, Iron and Manganese in Different Agro Ecological Zones, Soils and Districts of Tigray, Ethiopia. Tigray Agricultural Research Institute, Mekelle, Ethiopia. 2012.

[22] Anonymous. Agro Ecological Zonation of Ethiopia. Ministry of Agriculture, Addis Ababa, Ethiopia. http://www.fao.org/ag/AGP/AGPC/doc/counprof/ethiopia/ethiopia.htm (January, 2014). 2000.

[23] Hawzen Office of Agriculture and Rural Development, unpublished metrological data, Hawzen, Tigray, Ethiopia. 2013.

[24] Food and Agricultural Organization (FAO). Web LocClim, Local Climate Monthly Estimator. http://www.fao.org/sd/locclim/srv/locclim.home (February, 2014). 2002.

[25] M.L. Jackson. Soil Chemical Analysis. Prentice Hall of India Pvt. Ltd., New Delhi. 1967.

[26] P.R. Day. Particle fractionation and particle-size analysis. In: C.A. Black. D.D. Evans. J.L. White. L.E. Ensminger. F.E. Clark. (eds). Method of Soil Analysis, Part 2. ASA, Inc. Madison, Wis, U.SA. 1965.

[27] S.R. Olsen. C.V. Cole. F.S. Watanabe. and L.A. Dean. Estimation of available phosphorus in soil by extraction with sodium bicarbonate. USDA Circular 939:1-19. Gov. Printing Office Washington D.C. 1954.

[28] J.M. Bremner. and C.S. Mulvaney. Total nitrogen. In A.L. Page. R.H. Miller. and D.R. Keeney. (eds). Methods of Soil Analysis, Part 2. Argon. Mongr. 9. 2 eds. ASA and SSSA, Madison, WI. 1982.

[29] C.A. Black. D.D. Evans. J.L. White. L.E. Ensminger and F.E. Clark. Method of Soil Analysis, Part 2. ASA, Inc. Madison, Wis, USA. 1965.

[30] G. R. Nziguheba. C.A. Merckx. Palm. and P. Mutuo. Combined Use of *Tithonia diversifolia* and Inorganic Fertilizers for Improving Maize Production in a Phosphorus Deficient Soil in Western Kenya. In: A. Bationo. (eds). Managing Nutrient Cycles to Sustain Soil Fertility in Sub Saharan Africa. Academy Science Publishers. Nairobi, Kenya. 2004.

[31] J.K. Syers. A.E. Johnston. and D. Curtin. Efficiency of Soil and Fertilizer Phosphorus Use: Reconciling changing concepts of soil phosphorus behavior with agronomic information. FAO Fertilizer and Plant Nutrition Bulletin 18. Food and Agricultural Organization of the United Nations. Rome. 2008.

[32] American Association Cereal Chemists (AACC). Approved Methods of the American Association Cereal Chemists. American Association of Cereal Chemists, Inc., St. Paul, Minnesota. 2000.

[33] J.R. Landon. Booker Tropical Soil Manual: A handbook for soil survey and agricultural land evaluation in the tropics and sub tropics (ed.). Longman Scientific & Technical. Booker Tate. UK. 1991.

[34] CIMMYT. From Agronomic data to farmers recommendations: An economic training manual. Completely revised edition, Mexico, D.F. 1998.