Effects of Green Manure Crops and Nitrogen Rates on Wheat (*Triticum Aestivum* L.) Yield in Northwestern Ethiopian Highlands

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Abstract

Nitrogen is the most important nutrient to improve crop yield, however huge application rate has negative impact on aggravating soil acidity and environmental pollution. This experiment was conducted in 2020 and 2021 years in Debre Elias district to select the most effective green manure crop and supplementary N rate for bread wheat yield. A split-plot design with main plots of N rate (0, 60, 80 and 100 kg/ha) and subplots of green manuring (control, lupine, vetch and fenugreek) treatments were replicated three times. Soil organic carbon and total nitrogen and green manure biomass yield were significant while soil pH and C:N ratio were not significantly influenced by green manure crop. The highest green manure biomass yield (13.073 t/ha), soil organic matter (2.04%) and, total N (0.131%) were recorded from lupine green manure. On the other hand, bread wheat yield and yield related parameters were significantly affected by green manuring and N rate; however spike length, the number of kernels per spike and, grain yield were significant to the interaction effect of N rate and green manure. The longest date of maturity (90 & 92days) and plant height (84 & 86 cm) were observed in lupine manure and maximum N (100 kg/ha) while the shortest date of maturity (87 & 83) and plant height (80.6 & 77.8 cm) from fenugreek manure and zero N fertilizer rate. Combined use of lupine manure and 80 kg/ha N fertilizer gave the highest grain yield (3.725 t/ha) and net profit (66,925 birr (1,620.85 USD) per ha) with acceptable marginal rate of return (MRR) of (66%). The farmers of the study area are advised to implement combined use of lupine green manure with supplementary 80 kg/ha N for sustainable wheat production.

Keywords: Bread wheat, Green manure biomass yield, Fenugreek, Green manuring, Lupine, Vetch

Introduction

Sustainable development is the dominating paradigm in environmental, economic and ecological issue in the 20th and 21st century (Redcliff, 2005, Spiertz, 2010). Application of mineral N fertilizer is important to increase crop yield; however huge fertilizer application had environmental pollution problem in soil, air and water sources. The excessive use of agrochemicals pollute the environmental conditions at a great extent particularly on the food produced under such farm system may not be safe or good quality (Arshad and Shah, 2010). On the other hand, green manure technology is environmental safe, low-cost method to restore soil organic matter and prevent rapid decline in soil fertility, a key cause of food insecurity of tropical smallholders (Becker and Johnson 1998).

According to Smil (2002) report, nitrogenous fertilizers have contributed much in world food production, about 40 percent per-capita food production in the past 50 years increased through the application of N fertilizers but most agricultural soils in Ethiopia are deficient in N nutrient. Nutrient depletion is the fundamental biophysical factor for declining per capita food production for the small-scale farmers of Africa and Ethiopia (Drechsel *et al*., 2004; Amare *et al*., 2005). Arable crops required the large amount of nitrogen nutrient, unfortunately the price of fertilizers has been inflated and becoming unaffordable to resource poor farmers (Lemaire & Gastal 1997; Makokha *et al*., 2001; Kayeke *et al*., 2007).

The price of wheat has been increased from year to year; as a result it initiated the farmers to increment of wheat through intensive use of chemical fertilizers at the expense of deteriorating soil quality (Makokha *et al*., 2001, Alemayehu, 2011). The huge and repeated application of chemical fertilizers alter the physicochemical and biological properties of soils besides it has negative impact on the depletion of organic matter, macro and micronutrients and aggravating topsoil erosion and acidity (IFPRI, 2010). High application rate of chemical fertilizer causes environmental pollution and economically low profitable. Thus, chemical fertilizers should be applied under the right soil conditions and with adequate physical soil and water management. Sole application of chemical fertilizer can lower soil pH (increasing soil acidify), decreasing the organic matter content and microbial activity but developing soil crust, increasing the incidence of pest as a result plant growth stunted and emit greenhouse gases (Pahalvi *et al*., 2021)

Wheat requires large amount of nitrogenous nutrient than other elements, for instance wheat required about 3.3 - 4.1% N nutrient by the weight of grain but it requires 1 - 1.17% P_2O_5 to weight of grain (Kumar *and* Goh, 2002; IPNI, 2008). An application of organic materials helps for the proper maintenance of soil fertility (Sameem *et al.*, 2002). Mineral N fertilizer application has eliminated a major elemental constraint with respect to enriching the soil stock of organic C and N originally managed by organic manure amendments and leguminous cultures (Hirel *et al.*, 2011). However, organic farming can eliminate many of the environmental problems of conventional agriculture (Arshad and Shah, 2010).

Green manure crops enrich soil fertility through incorporating the non-decomposed plant materials into soils. Green manure can either be grown in situ and incorporated in the field or grown elsewhere and brought in for incorporation in the field. Not all plants can be used as a green manure in practical farming. Green manures may be: plants of grain legumes such as pigeon pea, green gram, lupine, vetch, cowpea, etc while perennial woody legume plants, such as *Leucaena leucocephala*, *Gliricidia sepium*, *Cassia siamea*; and non-grain legumes, such as Crotalaria, Sesbania, Centrosema, Stylosanthes and Desmodium can be used for green manure. Because green manures add whatever they have absorbed from the soil, they in fact recycle soil nutrients from lower depths to the topsoil besides contributing to soil N through N fixation (FAO, 2006).

Green manuring increase the availability of soil nitrogen and more profitable practice for the resource-poor farmers for who could not able to afford the required mineral N fertilizer. Green manures can potentially accumulate up to 250 kg N ha^{-1} yr^{-1} and resulting 600-4100 kg ha^{-1} yield increment of subsequent crop and improve soil structure (Peoples and Herridge 1990; Giller and Wilson 1991). This scenario leads to rethinking about the benefit of integrating green manure crop with mineral fertilizer for sustainable improvement of crop yield. The green manure practice has been initiated in recent years due to the inflated price of chemical fertilizers and the occurrence more environmental pollution risk for sustainable crop production. Green manuring is not only improve soil nutrients but also helps to reduce the cost of fertilizer (Irin *et al*., 2019).

The selection of green manure crop is crucial for high N fixing capacity, the fast-growing and high-yielding legume crop showed two to five times great in N fixation than slow-growing and low-yielding legume crop (Allison, 1973). The legume crop with more biomass yield is more preferable for green manuring (Werner and Newton, 2005). Legumes have different capacities to accumulate biomass and fix nitrogen but for effective green manure crop with high biomass yield preferable (Tolessa *et al.*, 2001). The plant materials used as green manure differ in their chemical composition, rate of decomposition and nutrient elements released to the soil, thus various green manures have significant differences on soil chemical properties and crop yield responses (Adekiya *et al.*, 2019). Sustainable agriculture aims to minimize or avoid the use of non-renewable production inputs (Lazányi, 2001) meanwhile the studies conducted by Ethiopian Institute of Agricultural Research (EIAR) have been focused on crop response to the mineral N and P fertilizers only (IFPRI, 2010). Thus, meager information available on integrated use of green manure and mineral N fertilizer to improve productivity of bread wheat in Ethiopia in general and in the study area in particular. Therefore, this study was designed to determine the effect of green manuring and supplementary N rate to increase wheat yield. The specific objectives of this study were to:

- Evaluate the green manure crop biomass yield and its impact on soil chemical properties
- Investigate the effects of green manuring and fertilizer rates on wheat growth and yield

2. Materials and Methods

2.1. Description of the study area

This study was conducted at Yemezeghn kebele in Debre Elias district it located 342 km north-western of Addis Ababa in consecutive two years (2020 and 2021) through using identical design (Figure 1). Geographically, the site is lies between 10^{o}36’72”N of latitude and 37^{o}49’02” E of longitude and at 2189 masl altitude. The district has a mean annual rainfall of 1266 mm and its mean annual temperature ranges from 18-27°C and located on altitude ranging from 800 to 2200 m above sea level. Regarding to the distribution of agro-ecological condition 98% coverage of the district categorized under mid-highland (*Woyina Dega*) while the rest 2% under lowland (*Kola*) agro-ecological zone. The district is dominantly covered by *Nitisols*, *Leptosols*, *Camobisols* and *Acrisols* soils but the experiment was carried out on *Nitisol*.

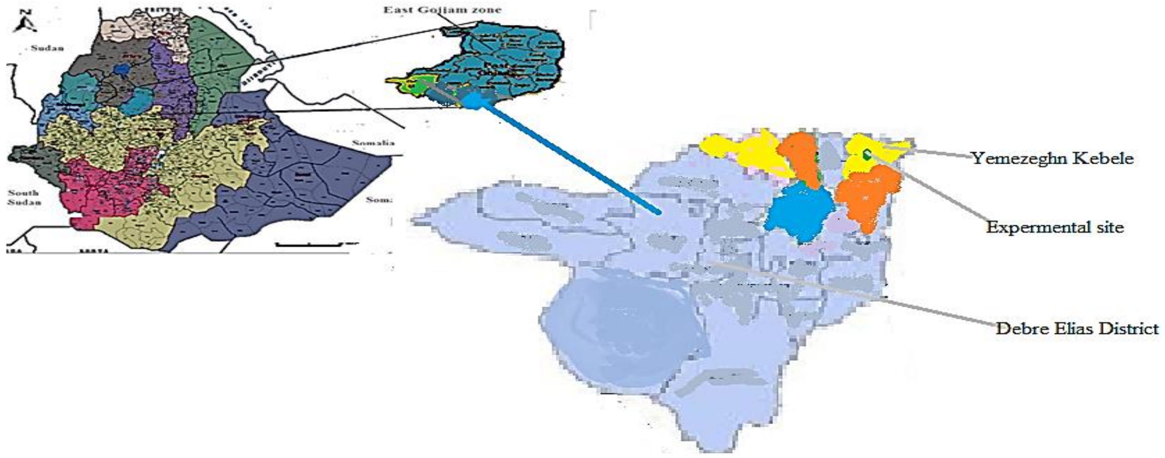

Figure 1. Shcmatic map of the study area

2.2. Treatments and Experimental Design

Three green manure crops (vetch, lupine and fenugreek) were collected from local market; urea and TSP (triple superphosphate) mineral fertilizers were used as a source of N and P, respectively. Kakaba (Picaflor) bread wheat was used as a test crop. This experiment was conducted by split plot arrangement based on a randomized complete block design with 3 replications. The design allowed for more precision chance to investigate the effect of subplot through sacrificed precision chance of main plot. The main plots were N rates (0, 60, 80 and 100 kg/ha) and subplots were different sources of green manures including control (plant cover), white lupine (*Lupinus albus*), vetch (*Vicia dasycarpa*) and fenugreek (*Trigonella foenum-graecum*).

2.3. Field preparation and crop sowing

The experimental field was primarily tilled by tractor and then by oxen-drawn *Maresha*. Finally, fine seed beds were prepared, manually. The gross size of the main plot was 3 m width x 9.5 m length (28.5 m^2) which consisted of four subplots while the size of each subplot was 3 m width x 2 m length (6 m^2). The space between blocks and main plots was 1 m while the space between subplots was 0.5 m. The fenugreek, vetch and lupine were sown with broadcast (scattering evenly) on each main plot at 67, 170 and 102 kg/ha rate, respectively while the control plots were allowed to grow cover plants as green mulch. Lupine seed was soaked in water for three days to hasten its germination, since its germination is slower than other green manures. A uniform rate of TSP (46 kg/ha P_2O_5) was applied for the whole plots. Green manure crops were allowed to grow for 53 days and then harvested at 3 cm height from ground, its above ground fresh biomass measured. The foliage was chopped into smaller pieces and thoroughly mixed with soil using hoe in to each plot

Bread wheat was sown after ten days of incorporation of green manure at 150 kg/ha rate with 20 cm inter-row spacing .The net plot size was determined by excluding two most outer rows and 0.25 m length from both sides of each plot as border effects, thus the net plot size was 2.4 m x 1.5 m (3.6 m^2). The predetermined 2/3 dose of urea fertilizer was applied during crop sowing while the remaining 1/3 dose applied at tillering stage of the crop. Uniform TSP (46kg/ha P_2O_5) was applied for the whole plots during sowing. Weeding was carried out, manually after 20 and 40 days of crop planting while the other agronomic practices uniformly practiced for the plots.

2.4. Soil sampling and analysis

Prior to starting the experiment soil samples were collected from 0-25 cm depth through zigzag fashion and then form a composite sample. Before bread wheat sowing soil samples were collected from each green manure applied subplots for determination of selected soil properties.

The collected soil samples were air dried and ground to pass through 0.5 mm sieve for the analysis of organic carbon and total N. while for pH and texture it was passed through 2 mm sieve size for analysis. Soil pH was determined from the filtered suspension of 1:2.5 soils to water ratio using a digital pH meter (potentiometer) while its texture identified by the hydrometer method (Day, 1965). Organic carbon content was measured by following the wet digestion method as outlined by Walkley and Black (1934) but its total N was estimated through titration (Jackson, 1958). Accordingly, the soil was clay in texture, strongly acidic, low in organic matter and total N content in both fields (Table 1).

Table 1. The physicochemical properties of soil

Soil test	Unit	2020	2021	Mean
Soil texture		Clay	Clay	Clay
Clay	%	67	71	69
Sand	%	12	11	11.5
Silt	%	21	18	19.5
pH		5.03	4.86	4.95
Organic carbon	%	1.01	0.96	0.99
Total nitrogen	%	0.109	0.105	0.107
Organic matter	%	1.74	1.66	1.7

2.5. Data collection

The above ground fresh biomass weights of each green manure were measured from each plot and then the average weight was taken from each block. Days to 50% emergence and heading and 90% maturity of bread wheat were recorded at specific phenological stages. The number of tillers was collected from five randomly selected plants from net plot area at late tillering stage. Plant height, spike length and number of kernels per spike were determined from five randomly selected plants from a net-plot area of 3.6 m^2 at physiological maturity. Plant height was measured from the ground level to the tip of the crop while the spike length measured from base of spike to the tip of spike. The percentage of lodged plant (deviated more than 45^o from its vertical axis) was computed from randomly sampled 0.5 m row length at physiological maturity. Grain, straw and biomass yields were measured through adjusting moisture content then converted into hectare base.

2.6. Statistical analysis

The collected data were subjected to analysis of variance by using Statistical Analysis Software (SAS) version 9.1. Significant differences among treatments means were delineated by least significant differences among treatments at probability level of 5%.

2.7. The economic analysis

The economic analysis to identifying the most profitable option was carried out according to CIMMYIT partial budget analysis method (CIMMYIT, 1988). The costs of green manure seed, N fertilizer and labor were collected during the application season from local market and computed in a hectare base. The average market prices of bread wheat grain and straw were collected from local market during harvesting season. Accordingly, the average price of bread wheat grain was 21 birr (0.51 USD) per kg while its straw 25 birr (0.61 USD) per 100 kg weight. Seeds of fenugreek, vetch and lupine were sown at 67, 170 and 102 kg/ha rate for green manuring and their costs were 100 birr (2.42 USD), 35 birr (0.85 USD) and 15 birr (0.36 USD) per kg weight, respectively. While costs of labor for green manuring equated based on their type of crop, thus for green manuring of plant cover, lupine, vetch and fenugreek required about 2, 10, 12 and 14 person/day, respectively. The price of urea was 16 birr (0.39 USD) per kg weight while the cost for labor was estimated at 150 birr (3.63 USD) per person per day.

Following CIMMYIT partial budget method, total variable cost, gross benefit and net benefit was calculated. The treatment was arranged in increasing order in terms of TVC and then the dominance analysis was performed to exclude dominated treatments from the marginal rate of return analysis in order to recommend economically profitable treatments (CIMMYIT, 1988)

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3. Results and Discussions

3.1.Green manure crop

3.1.1. The biomass yield of green manure

The above ground fresh weight was highly significantly ($p<0.01$) influenced by the type of green manure. The highest biomass yield (13.1 t/ha) was recorded from lupine and followed from vetch (8.3 t/ha),which might be due to the performance of lupine in acid soils (pH 4.5) but less in neutral or alkaline soils (Danute *et al.*, 2018). Meanwhile, the lowest fresh biomass yield (5.395t/ha) from fenugreek but it had statistical parity result with control plot (Table 2). In line with this finding Talgre (2013) disclosed that various legume crop had significant difference in fresh biomass yield. Generally, the higher fresh biomass yields of lupine and vetch, the lower fresh biomass yields of fenugreek and control plots were recorded in 2020 than 2021 (Table 2).

Table 2 Fresh biomass yield of green manure from the experimental sites

Green manure	2020	2021	Mean
Lupine	14.57^{a}	11.58^{A}	13.08^{a}
Vetch	8.47^{b}	8.12^{B}	8.30^{b}
Fenugreek	5.17^{c}	5.62^{C}	5.40^{c}
Plant cover (Control)	5.31^{c}	5.67^{C}	5.49^{c}
SE$\pm$	0.502	0.805	0.65
LSD (5%)	1.33	1.69	1.51

Means with the same letter within a column are not significantly different at $p<0.05$

3.2.Selected soil chemical properties after incorporation of green manure

The analysis results of soil test values before sowing of bread wheat indicated that the organic carbon and total nitrogen were significantly affected by application of green manure but soil pH and, C:N ratio were not significantly influenced with green manuring. Effects of green manure on properties of soil depend on the quality of green manure crop since it has various chemical compositions. In line with this finding Adekiya *et al.* (2019) disclosed that application of green manure significantly increased organic matter and total N content of soil as compared to the control but no significant differences in the values of pH between the control due to its chemical composition of the plants. Green manure application increases the organic carbon and N contents of soil, as a result improve the productivity of crops. Besides, green manure application enhances the recycling of soil nutrients as a result the availability of soil N and P increased (Tahsina and Rafiqul, 2016, Sharma *et al*., 2017).

Soil pH

Even though, soil pH was not significant to green manuring, the highest pH value (5.01) obtained from plots with fenugreek manure but the lowest pH (4.79) from the control treatment. However, among green manure, vetch had the lowest pH value (4.93) (Table 3). It agrees with Danute *et al*. (2018) who reported that the application of green manure slightly increased the pH of soils.

Table 3. Soil chemical property values due to green manure application

Green manure	pH	Organic carbon	Total N	C:N ratio
Lupine	4.99	1.182[a]	0.131[a]	9.12
Vetch-	4.93	1.107[ab]	0.119[ab]	9.88
Fenugreek	5.01	1.082[ab]	0.113[b]	9.22
Control	4.79	0.985[b]	0.107[b]	9.32
SE	0.09	0.011	0.0002	1.443
CV	2.09	9.76	2.086	
LSD (5%)	0.362	0.128	0.015	

Means with the same letter within a column are not significantly different at $p<0.05$

Soil organic carbon or matter

Organic matter has a significant role to improve soil properties (Fenton *et al*., 2008; Roman *et al*., 2015). The highest organic carbon (1.182%) was recorded from lupine green manuring and then followed by vetch green manuring but the lowest organic carbon (0.985 %) from control plots (Table 3). Since the amount of organic matter add to soil depends up on climatic conditions, soil and vegetation types, Soil organic matter accumulation depends largely on the quantity of organic matter input. However, the analysis results of soil organic matter were categorized under low level.

Total nitrogen content

The highest N (0.131%) was recorded from lupine green manure plots and then followed by 0.119% N fenugreek green manure but the lowest N (0.107%) from the control treatment (Table 4). Leguminous green manures have the ability to fix nitrogen from the air and add it into the soil, however lupine fix 25% more free nitrogen than clovers and 28% more than peas and beans.

Table 4. Mean separation test results of phenological and growth parameters

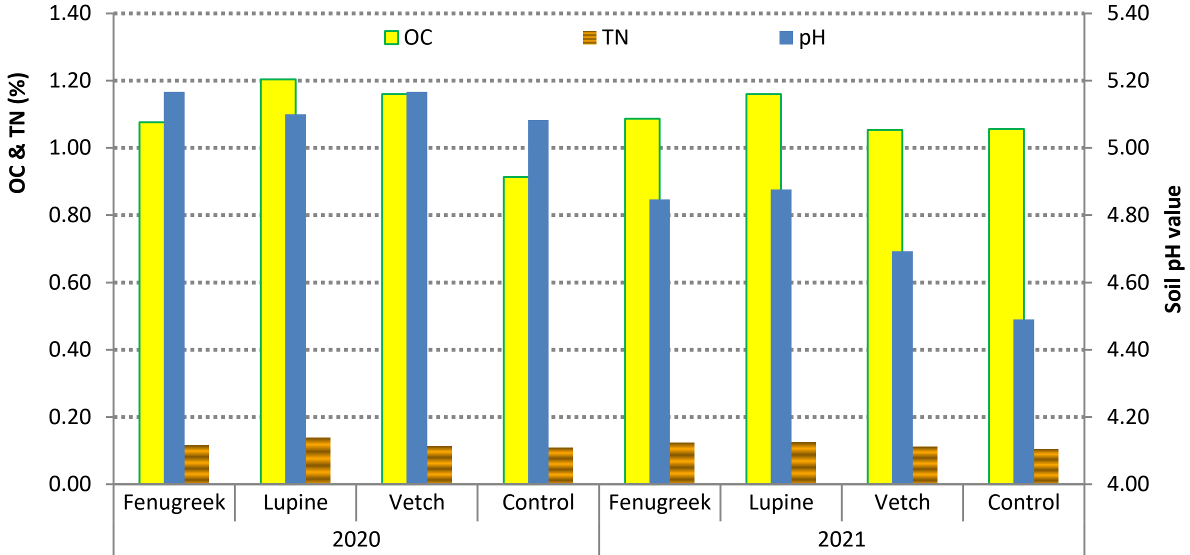
Effects	DH	DM	TNT	PH
Sub plot (green manure crop)				
Lupine	53.92[A]	90.17[a]	3.6[A]	84.83[a]
Vetch	51.88[B]	88.04[b]	3.03[B]	80.46[b]
Fenugreek	51.42[B]	87.46[b]	2.53[C]	80.79[b]
Plant cover	51.83[B]	87.04[b]	2.02[D]	81.79[ab]
LSD	1.77	1.05	0.3	3.47
Main plot (N rate in kg/ha)				
0	48.79[c]	83.79[D]	2.45[c]	77.83[C]
60	51.00[b]	87.04[C]	2.53[c]	81.42[B]
80	54.00[a]	89.75[B]	2.92[b]	82.21[B]
100	55.25[a]	92.13[A]	3.29[a]	86.42[A]
LSD	1.77	1.05	0.3	3.47
SE±	9.5	3.35	0.27	36.36
R^2	49.57	80.8	68.73	41.12

DH= Days to heading, DM= Days to maturity, TNT= Total number of tiller, PH= Plant height Means with the same letter within a column are not significantly different at $p<0.05$

C:N ratio

The ratio was not significantly affected by green manuring but the highest C:N ratio (9.88) was observed from vetch green manure while the lowest (9.12) from lupine green manure (Table 3). Applications of green manure gave low C:N ratios which favored decomposition and a short-term increase labile N pool.

Mineralization rates depend on the quality of organic matter (Tejada & Gonzalez, 2006). In this experiment C:N ratio values were grouped in to low categories, thus soil has no problem of N immobilization. A high C:N ratio (> 25) generally leads to immobilization: nitrogen is either immobilised by microorganisms during the decomposition of organic matter. However, the higher soil values were recorded in 2020 season than 2021 season. Maximum soil organic carbon and total N values were recorded from lupine applied plots whereas maximum pH value observed from fenugreek and vetch green manuring (Figure 2).



	Fenugreek 2020	Lupine 2020	Vetch 2020	Control 2020	Fenugreek 2021	Lupine 2021	Vetch 2021	Control 2021
OC	1.08	1.20	1.16	0.91	1.09	1.16	1.05	1.06
TN	0.12	0.14	0.11	0.11	0.12	0.12	0.11	0.11
pH	5.17	5.10	5.17	5.08	4.85	4.88	4.69	4.49

Figure 2. Soil properties due to green manuring in 2020 and 2021 harvesting season

3.3.Phenological and growth parameters of bread wheat

Days to emergence and heading

Crop emergence was not significantly affected by green manure and N fertilizer rate. According to Elfinesh *et al*. (2011) and Biruk and Demelash (2016) reports the emergence of crop is affected by ability of utilization reserve food materials, moisture and temperature.

However, days to heading was highly significantly ($p<0.01$) affected by N rate but significantly influenced by green manuring while insignificant to their interaction effect. Similarly, the days to heading of teff was highly significantly ($p<0.01$) affected by the main effects of chemical fertilizer (Alemu *et al*., 2016). The longest date of heading was observed on plots that received lupine manuring and high N rate. Meanwhile, early heading crop observed on the plots received fenugreek manuring and low N rate (Table 4)

Days to maturity

The maturity of the crop was highly significantly ($p<0.01$) affected by individual effects of green manure and N rates. Delayed matured crop was recorded from lupine green manuring while early matured crop from crop covered (no manure crop). On the other hand, delayed maturity crop was observed on the main plot that received higher urea but early matured crop from low N rate (Table 4). High N rate of application delayed the physiological maturity of bread wheat (Getachew, 2004). Maturity of the crop was delayed in 2020 season by 2-5 days as compared with 2021 season.

Total number of tillers per plant

Total tiller number was highly significantly (p<0.01) affected by individual effects of manure and N rate application. The highest tiller number was recorded from lupine manure while the lowest from cover crop. Besides, the number tillers increased with N rate (Table 4). The analysis results in seasons indicated that the higher tiller numbers per plant (4.17) was recorded in 2020 than 2021 (3.93).

Plant height

Plant height was highly significantly (p <0.01) affected by main effect of N fertilizer rate but insignificant to green manure and their interaction effects. The longest plant height was recorded from high N rate but the shortest height from the control (zero N) (Table 4) it might be due to N fertilizer application enhance the growth and development of plants (Haftamu *et al.*, 2009). However, the longest crop height by 5-7 cm was recorded in 2021 than in 2020

3.4.Yield and yield components of bread wheat

Spike length

Spike length was highly significantly (p <0.01) affected by main effects but significantly (p<0.05) to their interaction effect of green manure and N rate. Maximum spike length was observed from the individual effects of 80 kg/ha N, lupine and vetch green manuring. However, the minimum spike length was recorded from their control (Figure 3). In line with this finding, spike length of wheat was increased by 12–36% over control due to various parthenium green manure amendments while spike length of the crop was increased by 31% due to NPK fertilizer over control treatment (Arshad and Shah, 2010). Similarly, Mitiku and Asnakech (2016) found that maize ear length increased with N rate.

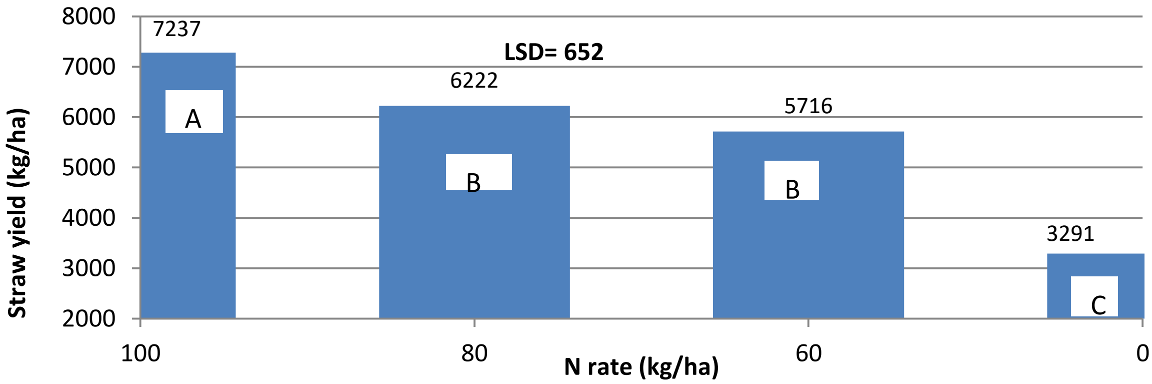


Figure 3. Effects of N rates on bread wheat straw yield

On the other hand, the maximum spike length of the crop (10.33cm) was recorded from combined use of 100 kg/ha N and lupine green manure but it had statistical parity with the treatment that received 80 kg/ha N and lupine manure. However, the minimum spike length was obtained from the control (0 N and plant cover) (Table 5). In line with this finding, Melkamu (2018) reported that maximum and minimum spike length obtained from plot treated with 100 % inorganic fertilizer and control, respectively. On the other hand, combed use of lupine manure and 100 kg/ha N gave the maximum spike length (10.33 cm) but statistical parity with the treatment that received lupine manure and 80 kg/ha N. The minimum spike length (7.97 cm) observed from their control treatment since an application of green manure and N fertilizer helps to release nutrient elements slowly during the period of crop growth (Singh *et al*., 1990).

Table 5. Spike length (cm) due to combined application of N fertilizer and green manure

	Green manure			
N fertilizer (kg/ha)	Lupine	Vetch	Fenugreek	Control (plant cover)
0	7.97f	8.1def	6.02g	6.83g
60	8.15def	8.4cdef	8ef	7.97f
80	10ab	9.25bc	8.85cdef	8.67cdef
100	10.33a	8.97cde	9cd	8.3cdef
LSD	0.97			

Means with the same letter (s) are not significantly different at 5% level

Number of kernels per spike

Similarly, N rate and green manuring had highly significant ($p<0.01$) influence on number of kernels and significantly ($p<0.05$) affected by their interaction effect. Numbers of kernels were increased linearly with N rate. This finding agree with Usman *et al*. (2020) who reported that the highest number of kernels per spike (48.3) was obtained from the highest NPSB fertilizer rate (150 kg/ha). However, the maximum number of kernels per spike was obtained from lupine manure but the minimum kernels recorded from their control treatment. On the other hand, the maximum number of kernels (57.83) per spike was recorded from combined use of lupine manure and 100 kg/ha N rate while the minimum number of kernels obtained from the treatment that received sole fenugreek green manure (Table 6).

Table 6. Number of kernels per spike by interaction of N rate and green manure

N fertilizer	Green manure			
(kg/ha)	Lupine	Vetch	Fenugreek	Control
0	30.67[ghi]	30.67[ghi]	25.67[i]	27.5[hi]
60	43.83[bcdef]	42.5[bcdef]	35.5[efghi]	33.67[fghi]
80	46.83[bcd]	47.67[abc]	39.33[cdefg]	36.5[efgh]
100	57.83[a]	50[ab]	44.83[bcde]	39.33[cdefg]
LSD		10.5		

Means with the same letter (s) are not significantly different at the 5% level

Thousand seeds weight

Seeds weight was highly significantly ($p<0.01$) affected by N rate but insignificant to the other effects. The highest weight (49.17g) of the seeds was recorded from the maximum N rate but it had statistical parity with the treatment that received 80 kg/ha N while the lowest seeds weight (41.69 g) was observed from zero N plots. In contrary to this finding Pramanik *et al*. (2004) disclosed that levels of nitrogen had significant influence on yield and yield components of transplanted rice.

Grain yield

Grain yield was highly significantly ($p<0.01$) affected by the main effects and significantly ($p<0.05$) affected by the interaction effect of green manure and N rate. Similarly, Ehsan *et al*. (2014) found wheat grain yield was significantly increased by combined application of green manures and mineral fertilizers. Mean separation test for individual effects indicated that the highest green yield of 3237 and 2894 kg/ha recorded from 100 kg/ha N and lupine green manure, respectively. In line with this finding Talgre *et al*. (2009) disclosed that spring wheat gave the highest yield from the preceding crop by lucerne. Okubay (2019) reported that the highest grain yield of wheat from 69 kg N ha^{-1} rate with super granular urea (SGU) fertilizer.

On the other hand, the highest grain yield (3794 kg/ha) was obtained from the combined use of 100 kg/ha N and lupine manure but it had statically parity with 3725 kg/ha grain yield from the treatment that received lupine green manure and 80 kg/ha N rate. However, the lowest grain yield of 1157 kg/ha was recorded from the sole use of fenugreek manure but it had statically parity with all treatments that received sole green manure (Table 7). Thus, the lupine green manure with supplementary 80 kg/ha N was found optimum to increase bread wheat yield in the study area and for the similar agro-ecology. The analysis results in experimental seasons revealed that more grain yield was recorded from the same treatment of 2020 cropping season than 2021 season it might be due to the climatic conditions of the season.

Table 7. Grain yield as influenced with interaction of N rate and green manure

N fertilizer	Green manure			
(kg/ha)	Lupine	Vetch	Fenugreek	Control
0	1433[h]	1277[h]	1157[h]	1205[h]
60	2624[de]	2357[e]	1796[g]	2082[f]
80	3725[a]	3079[bc]	2810[cd]	2954[c]
100	3794[a]	3247[b]	2933[c]	2976[bc]
LSD	278			

Means with the same letter (s) are not significantly different at the 5% level

Straw yield

Straw yield was highly significantly ($p<0.01$) affected by N rate but insignificant to green manure and to their interaction effect. It agrees with Okubay (2019) who reported that an application of N fertilizer led to significantly different in wheat straw yields. In contrary with this finding, Tahsina and Rafiqul (2016) revealed that residual effects of green manures with different levels of nitrogen showed a positive effect on grain and straw yields The highest straw yield (7237 kg/ha) was recorded from maximum N rate (100 kg/ha) but the lowest straw yield (3291 kg/ha) was obtained from the control treatment. In line with this result Okubay (2019) found the highest straw yield was observed from maximum N rate.

Biomass yield and harvest index

Wheat biomass yield and harvest index were highly significantly ($p<0.01$) influenced by N rate and green manuring but insignificant to their interaction effect. The highest biomass yield of 10506 and 8875 kg/ha were recorded from individual effects of 100 kg/ha N and lupine manure, respectively but the lowest biomass yield from their control plots. The maximum harvest index (HI) 33.6 and 32.3% were observed from 80 kg/ha N and lupine manure, respectively but the lowest HI value from their control and fenugreek treatment (Table 8).

Table 8. Wheat biomass yield and harvest index as influenced by N rate and green manure

Treatment	Biomass yield (kg/ha)	Harvest index (%)
N rate		
0	4559[D]	28.26[c]
60	7930[C]	28.41[c]

80	9405[B]	33.6[a]
100	10506[A]	31.16[b]
LSD	718.9	2.17
Green manure		
Control	7518[c]	31.16[AB]
Fenugreek	7656[bc]	28.13[C]
Vetch	8352[ab]	30.01[BC]
Lupine	8875[a]	32.28[A]
LSD	719	2.09
CV	1.99	1.98

Means with the same letter within a column are not significantly different at $p<0.05$

3.5.Economic analysis results

Partial economic analysis revealed that eleven treatments were categorized under dominated by another treatment. The combined use of lupine green manure and 80 kg/ha N gave the maximum net profit of 66,925 birr (1,620.85 USD) per ha with acceptable MRR of 66% but the combined lupine green manure and 100 kg/ha N treatment dominated one (Table 9). Thus, the combined lupine manure and 80 kg/ha N give the marginal profitable wheat yield for the study area and also for similar agro-ecological conditions.

Table 9. The economic analysis result

Treatment (N (kg/ha)*GM)	GY kg/ha	AGY	GYV	SY	ASY	SYV	GFB (EthB)	TVC	NB (EthB/ha)	MRR (%)
0*C	1205	1085	22774.5	2827	2544	636	23411	300	23111	
0*L	1433	1290	27083.7	3566	3209	802	27886	2230	25656	132
60*C	2082	1874	39349.8	5251	4726	1181	40531	2386	38145	806
80*C	2954	2659	55830.6	5913	5322	1330	57161	3083	54078	228
100*C	2976	2678	56246.4	6863	6177	1544	57791	3778	54013	D
60*L	2624	2362	49593.6	6087	5478	1370	50963	4317	46647	D
80*L	3725	3353	70402.5	6824	6142	1535	71938	5013	66925	66
100*L	3794	3415	71706.6	7445	6701	1675	73382	6467	66915	D
0*V	1277	1149	24135.3	3378	3040	760	24895	7630	17265	D
0*F	1157	1041	21867.3	3393	3054	763	22631	8660	13971	D
60*V	2357	2121	44547.3	6187	5568	1392	45939	9717	36222	D
80*V	3079	2771	58193.1	6170	5553	1388	59581	10413	49168	D

60*F	1796	1616	33944.4	5338	4804	1201	35145	10747	24398	D
100*V	3247	2922	61368.3	7750	6975	1744	63112	11108	52004	D
80*F	2810	2529	53109	6142	5528	1382	54491	11443	43048	D
100*F	2933	2640	55433.7	7055	6350	1587	57021	12128	44893	D

Whereas GM= green manure, L= Lupine, V= Vetch, F= Fenugreek, C= Control GM= Green Manure, GY= grain yield, AGY= actual grain yield, GYV= grain yield value, SY= straw yield, GFB= Gross field benefit, EthB= Ethiopia Birr, TVC= total variable cost, NB= Net benefit, MRR= Marginal rate of return, D= dominated

4. Conclusion and recommendation

The analysis results of green manuring revealed that the highest fresh biomass yield was observed from lupine green manure which ultimately greatly increased soil organic matter and nitrogen contents of soils. On the other hand, the wheat agronomic parameters were highly significantly influenced by main effects of N rate and green manure except spike length and number of kernels per spike which were significantly affected by their interaction effect. The highest values of the parameters were observed from maximum N rate and lupine green manure in both main and interaction effects. Besides, the economic analysis disclosed that the maximum net profit of 66,925 birr (1,620.85 USD) per ha obtained from combined lupine green manure and 80 kg/ha N fertilizer then followed by the treatment that received combined lupine green manure and 100 kg/ha N fertilizer use, which gave a net profit of 66,915 birr (1,620.61 USD) per ha but it was dominated by another treatment. Hence, wheat yield can be improved by combined use of lupine manure and supplementary 80 kg/ha mineral N fertilizer. However, such type of studies should be repeated over various agro-ecological conditions to draw a comprehensive recommendation for different agro-ecological conditions.

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6. References

Adekiya, A., Agbede T., Aboyeji C.Dunsin O. Ugbe J. (2019). Green manures and NPK fertilizer effects on soil properties, growth, yield, mineral and vitamin C composition of okra (*Abelmoschus esculentus* (L.) Moench), *Journal of the Saudi Society of Agricultural Sciences*, Volume 18, Issue 2, Pages 218-223.

Alemayehu S., Paul D. and Sinafikeh A. (2011). Crop Production in Ethiopia: Regional Patterns and Trends. Development Strategy and Governance Division, International Food Policy Research Institute, Ethiopia Strategy Support Program II, Ethiopia, ESSP II Working Paper 16.

Alemu A., Tamado T. and Jemal A. (2016). Effects of compost and inorganic np rates on growth, yield and yield components of teff (*Eragrotis teff* (Zucc.) Trotter) in Girar Jarso district, central highland of Ethiopia, *Journal of Fertilizers & Pesticides*.

Allison F. E. (1973). Soil organic matter and its role in crop production. *Developments in Soil Science* 3. Elsevier scientific publishing company. Amsterdam London New York.

Amare H., Joerg P., Edzo V., Demil T., Jan P. (2005). Assessment of soil nutrient depletion and its spatial variability on smallholders' mixed farming systems in Ethiopia using partial versus full nutrient balances. Agriculture, Elsevier B.V. Ecosystems and Environment 108 1–16.

Arshad J. and Shah M. (2010). Growth and yield response of wheat to EM (effective microorganisms) and parthenium green manure. African Journal of Biotechnology Vol. 9(23), pp. 3373-3381.

Becker M, Johnson A (1998) The role of legume fallow in intensified upland rice-based cropping systems in West Africa. *Nutr. Cycl. Agro-ecosyst*. 6:1-11.

Biruk G. and Demelash K. (2016). Effect of Nitrogen Fertilizer Level on Grain Yield and Quality of Malt Barley (Hordeum vulgare L.) Varieties in Malga Woreda , 52, 8–16.

Danute K., Regina R., Dalia A., Regina S. and Ieva J. (2018). Control of Soil pH, Its Ecological and Agronomic Assessment in an Agro ecosystem, Soil pH for nutrient availability and crop performance.

Day, P. (1965). Particle Fraction and Particle Size Analysis. In method of soil analysis. 185p.

Drechsel, P., Giordano, M. and Gyiele, L. (2004). Valuing nutrition in soil and water: concepts and techniques with examples from IWMI studies in developing world. IWMI Paper 82. IWMI, Colombo, Sri Lanka.

Ehsan S, Niaz A, Saleem I and Mehmood K. (2014). Substitution of major nutrient requirement of rice-wheat cropping system through Sesbania green manure. Sci. Agric. 8: 99-102.

FAO (2006). Plant nutrition for food security A guide for integrated nutrient management. FAO fertilizer and plant nutrition bulletin 16, edited by Roy R., Finck A., Blair G. and Tandon H. Italy, Rome.

Fenton M, Albers C, Katterings Q (2008). Soil organic matter. Agronomy Fact Sheet Series No. 41, New York: Cornell University Cooperative Extension.

Getachew F. (2004). Soil characterization and bread wheat (*Triticum aestivum*) response to N and P fertilization on Nitisols at Ayehu Research Substation in Northwestern Ethiopia. MSc Thesis Submitted to the School of Graduate Studies, Alemaya University. 71p.

Giller K Wilson K. (1991) Nitrogen fixation in tropical cropping systems. CAB, Wallingford, UK. 313 p.

Haftamu, G., Mitiku H., Charles F and Yamoah C. (2009). Tillage frequency, soil compaction and N rate effects on yield of teff (*Eragrostis teff* (Zucc) Trotter) in central zone of Tigray, Northern Ethiopia. 1: 82-94.

Hirel, B., Tétu, T., Lea, P.J., Dubois, F. (2011). Improving nitrogen use efficiency in crops for sustainable agriculture. Sustainability, 3, 1452–1485.

IFPRI (International Food Policy Research Institute), (2010). Fertilizer and soil fertility potential in Ethiopia, constraints and opportunities for enhancing the system. sustainable solution for ending hanger and poverty contributed by Gete Z., Getachew A., Dejene A., Shahid, R. Working paper, pp 1-66.

IPNI (International Plant Nutrition Institute), (2008). Plan winter wheat fertility programs. Plant nutrition today no: 8. www.ipni.net/pnt.

Irin. I., Biswas P., Ullah M. Roy T. and Khan M. (2019). Influence of green manure on dry matter production and soil health, *Bangladesh Agronomy Journal*, 22 (1): 39-45.

Kayeke J. Sibuga1 P., Msaky J. and Mbwaga A. (2007). Green Manure and Inorganic Fertilizer as Management Strategies for Witch weed and Upland Rice, African Crop Science Journal, Vol. 15, No. 4, 161 – 171.

Kumar, K., and Goh, K. (2002). Management practices of antecedent leguminous and non–leguminous crop residues in relation to winter wheat yields, nitrogen uptake, soil nitrogen mineralization and simple nitrogen balance. *European Journal of Agronomy*. 16: 295–308.

Okubay, G. (2019) Effect of type and rate of urea fertilizers on nitrogen use efficiencies and yield of wheat (*Triticum aestivum*) in Northern Ethiopia, Cogent Environmental Science, 5:1, 1655980, DOI: 10.1080/23311843.2019.1655980.

Lazányi, J. (2001). Effects of lupine green and root manure on yield of subsequent rye. Cereal research communication, Vol, 28, no 1, publisher Akadémiai Kiadó 175-182 pp.

Lemaire, G., Gastal, F. (1997): Nitrogen uptake and distribution in plant canopies. In: Lemaire, G. ed. Diagnosis of the nitrogen status in crops. Berlin, Springer. Pp. 3-44.

Makokha, S., Kimani S, Mwangi W., Verkuijl H. and Musembi F. (2001). Determinants of fertilizers and manure use in maize production in Kiambu district, Kenya. International Maize and Wheat Improvement Centre (CIMMYT) and Kenya Agricultural Research Institute.

Melkamu, H. (2018). Soil characterization and effects of different blended fertilizers on yield and yield components of food barley (*Hordeum vulgare* L.) on Nitisols at hulla district, southern Ethiopia.

Mitiku, W., Asnakech H. (2016). Effect of nitrogen fertilizer on growth and yield of maize (*Zea mays* L.) in Decha district, Southwestern Ethiopia. International Journal of Research, Vol. 4, No. 2 : 95- 100.

Pahalvi, H., Rafiya, L., Rashid, S., Nisar, B., Kamili, A.N. (2021). Chemical Fertilizers and Their Impact on Soil Health. In: Dar, G.H., Bhat, R.A., Mehmood, M.A., Hakeem, K.R. (eds) Microbiota and Biofertilizers, Vol 2. Springer, Cham. https://doi.org/10.1007/978-3-030-61010-4_1.

Peoples, M., Herridge D. (1990) Nitrogen fixation by legumes in tropical and subtropical agriculture. Adv. Agron. 44:155-223.

Pramanik, M., Sarkar M., Islam M. and Samad M. (2004). Effect of Green Manures and Different Levels of N on the Yield and Yield Components of Transplant

Aman Rice. Journal of Agronomy, 3: 122-125

Roman, P, Martinez M. and Pantoja A (2015). Farmer's Compost Handbook, Experiences in Latin America. Santiago.

Sameem, M, Wood T., Bain J. (2002). A systematic review on the use of fibrin glue for peripheral nerve repair. Plast Reconstr Surg;127:2381–2390.

Sharma, P., Laor Y., Raviv M., Medina S., Saadi I., Kransnovsky A., Vager M., Levy G., Bar-Tal A., Borisover M. (2017). Green manure as part of organic management cycle: Effects on changes in organic matter characteristics across soil profile. *Geoderma*, 305: 197-207.

Singh, Y., Singh B., Meelu O., Maskina M. (1990). Nitrogen equivalence of green manure for wet land rice on coarse textural soils. Int. Rice Res. Newslett., 15: 23-25.

Smil, M. (2002).The Earth's Biosphere: Evolution, Dynamics and Change: Environmental Science & Policy 6(6):549–550 pp.

Spiertz, H. (2010). Food production, crops and sustainability: Restoring confidence in science and technology. Current Opinion in Environmental Sustainability, 2, 439-443.

Tahsina, H., Rafiqul I. (2016). Residual effects of different green manures on the growth and yield of wheat. Asian Journal of Medical and Biological Research, 2(4):624-630 . DOI:10.3329/ajmbr.v2i4.31006

Talgre, L. (2013). Biomass Production of Different Green Manure Crops and Their Effect on the Succeeding Crops Yield. PhD Dissertation in Plant Production, Institute of Agricultural and Environmental Sciences, Estonian University, Republic of Estonia

Talgre, L., Lauringson E., Roostalu H., Astover A. (2009). The effects of green manures on yields and yield quality of spring wheat. Agronomy Research 7(1), 125-132.

Tejada, M., Gonzalez, J. (2006). Crushed cotton gin compost on soil biological properties and rice yield. *European Journal of Agronomy* 25, 22–29.

Tolessa, D., Tesfa B., Wakene N., Tenaw W., Minale L., Tewodros M., Burtukan M., Waga M. (2001). A review of fertilizer management research on maize in Ethiopia. *Second National Maize Workshop of Ethiopia. 12-16 November, 2001.*

Usman K., Tamado T., Wogeyehu W. (2020). Effects of blended (NPSB) fertilizer rates on yield components, yield and grain quality of bread wheat (*Triticum aestivum* L.) varieties at kulumsa, south-eastern Ethiopia. *International Journal of Research Studies in Biosciences* (IJRSB), Volume 8, Issue 9, 14-27.