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Effect of Farmyard Manure and Mineral Nitrogen and Phosphorus on Yield, Yield Components and Nutrient Uptake of Food Barley (*Hordeum vulgare* L.) Varieties in Kaffa Zone, Southwestern Ethiopia

Mitiku Woldesenbet[1] and Tamado Tana[2]
[1]*Mizan-Tepi University, Department of Plant Sciences, P. O. Box 260, Mizan Teferi, E-mail address: wesenbetmitiku@gmail.com, Ethiopia*
[2]*Haramaya University, School of Plant Sciences, P. O. Box 138, Dire Dawa, Ethiopia*

Abstract

Low soil fertility and inadequate soil fertility management practices have limited the productivity of barley in Kaffa Zone, southwestern Ethiopia. Thus field experiment was conducted to determine the effects of combined application of farmyard manure (FYM) with inorganic nitrogen and phosphorus (NP) fertilizers on yield, yield components and NP uptake of food barley. The treatments consisted of thirteen fertilizer combinations and two varieties in a factorial arrangement laid out in a randomized complete block design with three replications. Result showed that interaction of fertilizer management and variety gave significantly highest number of productive tillers m^{-2} of 191.33 in Adiyo and 182 in Ghimbo which were obtained for variety 'GABULA' with application of 5 t FYM ha^{-1} + 75% recommended rate of inorganic NP. The main effect of variety indicated that variety 'GABULA' gave significantly higher grain yield (2409 kg ha^{-1}) and harvest index (39.26%) in Adiyo and 2255 kg ha^{-1}and 38.02% in Ghimbo. The main effect of fertilizer indicated significantly highest grain yield of 2899 kg ha^{-1} and thousand grain weight of 42 g in Adiyo and 2581 kg ha^{-1} and 40.50g in Ghimbo from the application of 5 t ha^{-1} FYM in combination with 75% recommended rate of inorganic NP. The application of 5 t ha^{-1} FYM in combination with different rates of inorganic NP significantly increased NP uptake by grain, straw and total plant both in Adiyo and Ghimbo. Hence, it can be concluded that, the use of variety 'GABULA' and combined application of 5 t ha^{-1} FYM with 75% of recommended rates of inorganic NP can significantly increase food barley yield in the study areas.

Keywords: Farm yard manure, inorganic fertilizer, NP uptake

Introduction

Barley (*Hordeum vulgare* L.) is the fifth in area of production in Ethiopia (CSA, 2013). It is a hardy crop grown in a wide range of agro-climatic regions under several production systems. In Ethiopia, barley is grown mainly as a low input staple food crop in the higher altitudes, on steep slopes, eroded lands or in moisture stress areas (Teshome *et al*., 2008).

In Kaffa Zone, southwestern Ethiopia, barley is one of the major and widely cultivated small cereal crops. It is the most preferable crop in the study area as it can be produced twice per year. It covers an area of 8,700.39 ha with total production of 13305.793 t. However, its productivity is still low (1.52 t ha^{-1}) when compared to the average national yield of 1.84 t ha^{-1} (CSA, 2013).

Ethiopia in general and Kaffa zone in particular are characterized by diverse agricultural systems that are typically low input based subsistence farming. The soils of Kaffa Zone have sustained agricultural production for a very long time; as a result, their natural fertility has become extremely low. Moreover, with rapid population growth, fallow periods practiced in southwestern Ethiopia are replaced by continuous and intensive cropping without any fertility restoration of the soil in place. Though efforts have been made to develop improved production technologies, productivity of barley in production fields has remained very low (Bayeh and Grando, 2011). Soil fertility depletion in smallholder farms is recognized as the fundamental limiting factor responsible for the declining per-capita crop production including food barley in Kaffa Zone.

Thus, improving food production and soil resources has become an enormous challenge in the study area. Soil fertility replenishment has, therefore, been singled out as necessary for food barley production (Teshome *et al*., 2008). To realize this, soil fertility replenishment strategy that has the potential not only to supply nutrients but also arrest the mining of soil fertility.

Organic manures are key component of the soil and crop yield improvement measures because they carry out many functions in agro-ecosystem (Weil and Magdoff, 2004). Organic fertilizers can be used for crop production as a substitute for chemical fertilizers (Petric *et al*., 2009). Manure from livestock is key resource which can maintain soil quality through replenishing the organic matter content of the soil (Kler *et al*., 2007). But the application of only manure may not be effective for crop production due to the low nutrient contents, slow release of its nutrient and the high labour demands for processing and application (Palm *et al*., 1997).

On the other hand, smallholder farmers are unable to use the recommended dose of chemical fertilizers due to unavailability and high cost. Moreover, blanket recommendation of fertilizers, inadequate practices of soil conserve-ation and nutrient management contribute to the nutrient depletion. Hence, the rapid decline in agricultural production.

Though inorganic fertilizers have been used as one of the tools to overcome soil fertility problems and responsible for the huge increase in food production worldwide (Sanchez and Leakey, 1997), high and sustainable crop yields can be achieved only through the judicious use of inorganic fertilizers (Vlek, 1990). Attempts to introduce inorganic fertilizers must be based on type and level of fertilizers required for the crop (Sanchez and Leakey, 1997). Moreover, due to increasing prices of inorganic fertilizers growers may not afford applying inorganic fertilizers as needed. This calls for combined use of locally available organic fertilizers along with reduced amounts of inorganic fertilizers.

Therefore, integrated plant nutrient management with efficient recycling of organic materials such as animal manure in combination with mineral fertilizers is one of the options to increase crop production (Amanullah and Maimoona, 2007). The integration of organic and synthetic sources of nutrients not only supply essential nutrients but also has some positive synergistic relations leading to increased crop yield and reduced environmental threats. Abay and Tesfaye (2012) reported that highest barley yield was obtained from application of 46 kg N + 40 kg P + 50 kg K and 20 t ha^{-1} FYM over the application of 100% recommended rate of NPK fertilizer alone and the control. However, such studies have not been conducted in Kaffa Zone, southwestern Ethiopia. Thus, this study was conducted to determine the effects of combined application of farmyard manure (FYM) with inorganic NP on yield components, yield and NP uptake of food barley.

Materials and Methods

Description of the study areas

The experiment was conducted at Geri in Ghimbo district and Angesha in Adiyo district of Kaffa Zone, Southwestern Ethiopia, during 2014 *belg* cropping season from March to June. The research sites in Ghimbo and Adiyo districts are located at 8° 06´ N latitude, 36° 28´ E longitude, 2002 m.a.s.l altitude and 9° 05´ N latitude, 42° 33´ E longitude, 2350 m.a.s.l. altitude, respectively. The rainfall pattern of both areas is bimodal with the small rainy season (*belg)* from March-June and main rainy season (*meher)* from July-November (Banti, 2009). The annual total rainfall during the growing season was 950 mm in Ghimbo and 1024 mm in Adiyo, with respective mean annual temperature of 16.62 ^{0}C and 19.97 ^{0}C (Figure 1).

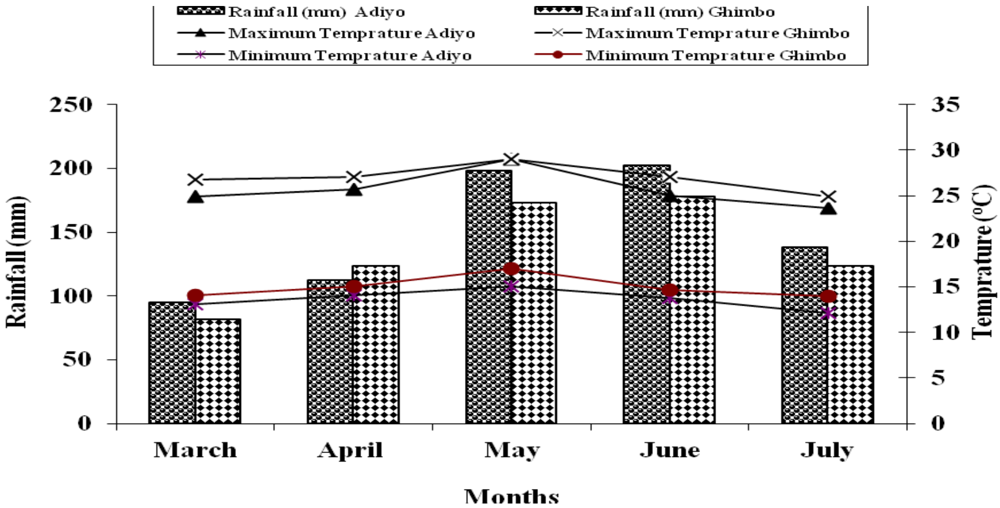

Fig 1. Rainfall (mm) and temperature (^{0}C) of the study areas during 2014 *belg* cropping season

Treatments and experimental design

The treatments consisted of factorial combination of thirteen fertilizer applications {2.5 t ha^{-1} FYM + 50% RRNP (recommended rate of NP fertilizer), 2.5 t ha^{-1} FYM + 75% RRNP , 5 t ha^{-1} FYM + 25% RRNP , 5 t ha^{-1} FYM + 50% RRNP , 5 t ha^{-1} FYM + 75% RRNP , 46 kg N ha^{-1} + 69 kg P_2O_5 ha^{-1}, 69 kg N ha^{-1} + 46 kg P_2O_5 ha^{-1}, 69 kg N ha^{-1} + 69 kg P_2O_5 ha^{-1}, 92 kg N ha^{-1} + 23 kg P_2O_5 ha^{-1}, 92 kg N ha^{-1} + 46 kg P_2O_5 ha^{-1}, 92 kg N ha^{-1} + 69 kg P_2O_5 ha^{-1}, 100% RRNP (23 kg N ha^{-1} + 46 kg P_2O_5 ha^{-1}) and no fertilizer control with two food barley varieties. The experiment was laid out in a randomized complete block design with three replications. Each plot had 12 rows of 20 cm apart each with 3 m length. The first rows from each side were considered as border. The second rows from each side of the plot were designated as sampling rows. In each plot, 0.2 m row length at the end of each row was left to avoid the border effect. Therefore, the net plot size was 1.6 m × 2.6 m (4.16 m^2).

Urea (46% N) and TSP (46% P_2O_5) were used as inorganic N and P sources whereas FYM was used as organic fertilizer source. The organic carbon, N, P, K and moisture contents of FYM used in the experiment were determined and the results indicated that it has OM content of 11.82%, total N of 1.52%, available P of 0.85%, exchangeable K of 2.73% and moisture content of 22.31%. Two improved food barley varieties called 'GABULA' (Acc. 231222/MS) released in 2007 by Hawassa Agricultural Research Center, Ethiopia and 'Diribe' (7th EMBSN 19/98) which was released in 2010 by the Kulumisa Agricultural Research Center, Ethiopia were used as test crops.

Prior to planting, soil samples were taken from a depth of 0-30 cm in a zig zag pattern from five spots across the experimental fields, composited, and analyzed in the national soil science laboratory, Addis Ababa, for soil physico-chemical properties and the results are depicted in Table 1.

Table 1. Physical and chemical characteristics of soil of the experimental sites in Adiyo and Ghimbo, southwestern Ethiopia

	Ghimbo		Adiyo		
Soil parameters	Value	Rating	Value	Rating	References
Textural class	Clay	-	Clay loam		
pH	5.90	Moderately acidic	6.20	Slightly acidic	Foth and Ellis (1997)
Organic carbon (%)	1.10	Low	1.19	Low	Havlin *et al*. (1999)
Total N (%)	0.11	Poor	0.09	Poor	Tekalign (1991)
Available P (mg kg^{-1})	6.90	Low	7.30	Low	Tekalign (1991)
CEC (cmol (+)/kg)	22.23	Medium	19.08	Medium	Landon (1991)

Experimental procedures

The experimental field was ploughed three times using a pair of oxen and the plots were leveled manually. Farmyard manure (FYM) was applied on dry weight basis three weeks prior to planting and thoroughly mixed with the soil. All P_2O_5 and half of the N fertilizer sources for the respective inorganic N and P_2O_5 treatments were applied at planting. The remaining half inorganic N fertilizer was applied at tillering stage of barley by side drilling. Seeds of barley varieties were planted using a seed rate of 120 kg ha^{-1} in row spaced 20 cm apart. Weeds were removed manually three times (at early tillering, maximum tillering and booting stages). Harvesting was done manually using hand sickles. The harvested product was sun dried for ten days, then threshed and winnowed.

Plant sampling and analysis for N and P

Plant samples collected at harvest were partitioned into straw and grain for the determinations of N and P concentrations in grain and straw and calculation of N and P fertilizer uptake. The samples were oven-dried at 65 ^{0} C to a constant weight and ground to pass through a 2 mm sieve. The samples were analyzed for nutrient content at the National Soil Testing Laboratory, Addis Ababa, Ethiopia. The straw, grain, and total N and P uptakes were calculated using the procedure below:

N and P uptake of grain (kg ha^{-1}) = N and P concentration of grain (%) × grain yield (kg ha^{-1})

N and P uptake of straw (kg ha^{-1}) = N and P concentration of straw (%) × straw yield (kg ha^{-1})

Total N and P uptake (kg ha^{-1}) = N and P uptake of grain (kg ha^{-1}) + N and P uptake of straw (kg ha^{-1})

Crop data collection

The number of total and productive tillers (ear bearing tillers) m^{-2} were counted from two randomly selected 1 m × 1 m area (5 rows of 1 m length) within the net plot area at physiological maturity and the average recorded. The spikes in the pre-tagged 10 plants were collected and the total grains from the above spikes were counted to record the number of grains spike^{-1}. Thousand grains were counted in each plot using electronic seed counter from a bulk of threshed grain and weight was determined using a sensitive balance at harvest and adjusted to 12.5% moisture content. The total aboveground dry biomass yield including straw and spike of plants in a net plot area was measured using sensitive balance after sun drying to for ten days. Straw yield was obtained by subtracting grain yield from total aboveground biomass. Harvest index was calculated as the ratio of grain yield to total aboveground dry biomass and expressed as percentage.

Data analysis

The agronomic and post harvest N and P uptake data were subjected to analysis of variance (GLM procedure) using SAS software program version 9.2 (SAS Institute, 2003). Homogeneity of variances for the two locations was evaluated using F-test as described by Gomez and Gomez (1984) and where it shows heterogeneity, separate analysis was done for the two locations. The Fisher's protected least significant difference (LSD) test at 5% probability level was employed to separate treatment means where significant treatment differences existed.

Results and Discussion

Yield components of barley

The number of total and productive tillers m^{-2} was significantly ($P<0.05$) affected by the interaction of variety with fertilizer management at both sites. The highest numbers of productive tillers m^{-2} of 191.33 in Adiyo and 182 in Ghimbo were obtained with the variety 'GABULA' when 5 t FYM ha^{-1} was applied in combination with 75% recommended rate of inorganic NP. On the other hand, the lowest numbers of productive tillers m^{-2} (39.33) in Adiyo and 28.88 in Ghimbo were recorded for variety 'Diribe' from the control (Table 2). The increase in tillering with increase in rate of FYM combined with inorganic NP might be due to the immediate availability of nutrients from the inorganic sources and the steady and increased availability of nutrients from organic sources (FYM) which resulted in increased uptake of nutrients by the plants. In line with this result, Jayanthi *et al*. (2002) reported that the application of FYM (6 t ha^{-1}) and inorganic NP (60%) gave higher number of fertile tillers m^{-2} in oat as compared to the application of 100% recommended NP fertilizer application. Similarly, Ranjithaa and Reddy (2014) reported the highest number of tillers of rice with the application of 10 t FYM ha^{-1} combined with inorganic fertilizers

Table 2. The interaction effect of variety and fertilizer management on number of total and productive tillers (m^{-2}) and aboveground biomass yield (kg ha^{-1}) of barley in Adiyo and Ghimbo, southwestern Ethiopia

		Adiyo		Ghimbo		
Variety	Fertilizer management	Number of total tillers	Number of productive tillers	Number of total tillers	Number of productive tillers	Above ground biomass yield
GABULA	2.5 t ha^{-1} FYM + 50% RRNP	171.33^{def}	165.00^{hi}	147.00^{gh}	142.00^{ijk}	4633.70^{j}
	2.5 t ha^{-1} FYM + 75% RRNP	176.33^{cde}	173.00^{c-g}	157.00^{efg}	151.00^{f-i}	5135.30^{i}
	5 t ha^{-1} FYM + 25% RRNP	182.33^{bcd}	178.00^{b-e}	178.00^{ab}	174.00^{ab}	5755.70^{f}
	5 t ha^{-1} FYM + 50% RRNP	193.0^{ab}	189.00^{ab}	178.66^{ab}	175.00^{ab}	6375.70^{d}
	5 t ha^{-1} FYM + 75% RRNP	195.6^{a}	191.33^{a}	186.33^{a}	182.00^{a}	6486.30^{cd}
	46 kg ha^{-1} N + 69 kg ha^{-1} P_2O_5	154.00^{ij}	152.00^{i}	136.00^{ij}	132.00^{lm}	4594.70^{j}
	69 kg ha^{-1} N + 46 kg ha^{-1} P_2O_5	151.00^{ij}	148.00^{i}	144.33^{hij}	137.00^{jkl}	4825.70^{j}
	69 kg ha^{-1} N + 69 kg ha^{-1} P_2O_5	156.66^{hij}	150.00^{i}	149.33^{fgh}	143.00^{h-k}	4667.70^{j}
	92 kg ha^{-1} N + 23 kg ha^{-1} P_2O_5	158.00^{hij}	151.00^{i}	162.00^{cde}	155.00^{ef}	5454.30^{gh}
	92 kg ha^{-1} N + 46 kg ha^{-1} P_2O_5	180.66^{b-e}	175.00^{c-g}	175.33^{b}	171.00^{bc}	6328.00^{d}
	92 kg ha^{-1} N + 69 kg ha^{-1} P_2O_5	184.66^{abc}	177.00^{c-f}	176.33^{ab}	171.00^{bc}	6362.30^{d}
	23 kg ha^{-1} N + 46 kg ha^{-1} P_2O_5 (100% RRNP)	134.00^{k}	129.00^{j}	122.33^{k}	117.00^{no}	4330.00^{k}
	Control	61.66^{l}	58.00^{k}	56.00^{l}	51.00^{p}	1595.70^{m}
Diribe	2.5 t ha^{-1} FYM + 50% RRNP	161.00^{f-i}	155.00^{gh}	142.66^{hij}	135.07^{kl}	5266.00^{hi}
	2.5 t ha^{-1} FYM + 75% RRNP	176.33^{e-h}	165.00^{gh}	148.00^{gh}	140.22^{jkl}	6056.00^{e}
	5 t ha^{-1} FYM + 25% RRNP	168.66^{e-h}	166.00^{fgh}	162.33^{cde}	158.07^{def}	6897.00^{b}
	5 t ha^{-1} FYM + 50% RRNP	185.66^{abc}	181.33^{a-d}	168.66^{bcd}	163.29^{cde}	7256.00^{a}
	5 t ha^{-1} FYM + 75% RRNP	189.33^{ab}	185.00^{abc}	171.66^{bc}	166.11^{bcd}	7432.70^{a}
	46 kg ha^{-1} N + 69 kg ha^{-1} P_2O_5	154.66^{ij}	149.00^{i}	133.66^{j}	125.18^{mn}	5299.0^{hi}
	69 kg ha^{-1} N + 46 kg ha^{-1} P_2O_5	152.00^{ij}	151.33^{i}	141.00^{hij}	138.18^{jkl}	5468.00^{gh}
	69 kg ha^{-1} N + 69 kg ha^{-1} P_2O_5	158.66^{g-j}	153.00^{i}	146.66^{ghi}	142.51^{hi}	5568.00^{gf}
	92 kg ha^{-1} N + 23 kg ha^{-1} P_2O_5	161.33^{f-i}	155.00^{hi}	149.66^{fgh}	144.29^{g-j}	6322.00^{d}
	92 kg ha^{-1} N + 46 kg ha^{-1} P_2O_5	171.00^{d-g}	166.00^{fgh}	156.33^{efg}	151.18^{fgh}	6676.00^{bc}
	92 kg ha^{-1} N + 69 kg ha^{-1} P_2O_5	174.33^{cde}	168.00^{efg}	160.00^{def}	152.27^{fg}	6702.00^{bc}
	23 kg ha^{-1} N + 46 kg ha^{-1} P_2O_5 (100% RRNP)	146.66^{j}	144.00^{i}	118.66^{k}	108.74^{o}	5236.00^{hi}
	Control	41.33^{m}	39.33^{l}	32.66^{m}	28.88^{q}	2545.00^{l}
Significance		**	*	**	**	*
LSD (0.05)		12.57	11.82	10.82	9.13	252.00
CV (%)		4.82	4.70	4.52	4.00	8.83

Means followed by the same letter within a column are not significantly different at P = 0.05 level of significance; * FYM = Farm Yard Manure, RRNP = Recommended Rate of Nitrogen and Phosphorus

The result also indicated that the main effects of variety and the application of different fertilizers had significantly ($P< 0.05$) affected the number of grains spike^{-1} at both sites. Variety 'Diribe' had significantly higher number of grains spike^{-1} of 36.13 in Adiyo and 34.33 in Ghimbo (Table 3). The difference between the varieties might be due to genetic characteristics.

The main effect of fertilizer indicated that the highest number (38.50) of grains spike^{-1} was obtained from combined application of 92 kg N ha^{-1} with 23 kg P_2O_5 ha^{-1} which was at par with when phosphorus was increased to 46 and 69 kg P_2O_5 ha^{-1} and also at par with the application of 5 t ha-1 FYM in combination with 50% and 75% inorganic NP in Adiyo (Table 3). Similarly, the application of 5 t FYM + 75% inorganic NP gave the highest number of grains spike^{-1} (36.11) in Ghimbo. On the other hand, the lowest number of grains spike^{-1} at both sites was obtained from the control (Table 3). The increase in number of grains spike^{-1} in response to the combined application of FYM with inorganic NP and increased level of NP might be due to enhanced availability of nutrients according to the need of the crop. In agreement with this result, Amanullah and Maimoona (2007) reported increased number of grains spike^{-1} of wheat with the rates of FYM and N fertilizer increased from control to 3 t FYM ha^{-1} + 90 kg N ha^{-1}. Sajjad *et al*. (2013) also reported that increased level of nitrogen fertilizer (125 kg ha^{-1}) resulted in the highest grains spike^{-1} of wheat.

The main effect of variety was not significant in Adiyo, but significant ($P<0.01$) in Ghimbo on thousand grain weight where variety 'GABULA' had higher thousand grain weight of 39.46 g in Adiyo and 38.65 g in Ghimbo (Table 3). On the other hand, the main effect of fertilizers had significant ($P< 0.01$) effect on thousand grain weight at both sites. However, variety and fertilizer interaction was not significant. Accordingly, maximum thousand grain weight of 42.00 g and 40.5g was recorded in Adiyo and Ghimbo with the application of 5 t FYM + 75% inorganic NP and 5 t FYM + 50% and 75% inorganic NP respectively, while the control recorded the lowest thousand grain weights at both locations (Table 3).

Table 3. The main effect of variety and fertilizer application on number of grains spike^{-1} (GS) and thousand grain weight (TGW) of barley in Adiyo and Ghimbo, Southwestern Ethiopia

	Ghimbo		Adiyo	
Factor	GS	TGW (g)	GS	TGW (g)
Variety				
GABULA	35.46	39.18	33.15^{b}	38.65^{a}
Diribe	36.13	39.46	34.33^{a}	37.18^{b}
Significance	NS	NS	**	**
LSD (0.05)	NS	NS	0.96	1.08
Fertilizer				
2.5 t ha^{-1} FYM + 50% RRNP	32.00^{cd}	38.00^{cde}	32.05^{de}	36.50^{bc}
2.5 t ha^{-1} FYM + 75% RRNP	34.50^{bc}	40.00^{abc}	33.55^{bcd}	37.75^{abc}
5 t ha^{-1} FYM + 25% RRNP	37.00^{ab}	41.50^{a}	34.55^{abc}	38.50^{ab}
5 t ha^{-1} FYM + 50% RRNP	38.50^{a}	41.50^{a}	36.09^{a}	40.50^{a}
5 t ha^{-1} FYM + 75% RRNP	38.50^{a}	42.00^{a}	36.11^{a}	40.50^{a}
46 kg ha^{-1} N + 69 kg ha^{-1} P_2O_5	34.33^{bc}	37.50^{de}	33.04^{cde}	36.00^{bc}
69 kg ha^{-1} N + 46 kg ha^{-1} P_2O_5	36.50^{ab}	38.50^{b-e}	33.60^{bcd}	38.50^{ab}
69 kg ha^{-1} N + 69 kg ha^{-1} P_2O_5	36.50^{ab}	39.50^{a-e}	34.13^{abc}	38.50^{ab}
92 kg ha^{-1} N + 23 kg ha^{-1} P_2O_5	38.50^{a}	40.50^{abc}	34.59^{abc}	40.00^{a}
92 kg ha^{-1} N + 46 kg ha^{-1} P_2O_5	38.50^{a}	41.00^{ab}	35.63^{ab}	40.00^{a}
92 kg ha^{-1} N + 69 kg ha^{-1} P_2O_5	38.50^{a}	40.67^{abc}	35.67^{ab}	40.00^{a}
23 kg ha^{-1} N + 46 kg ha^{-1} P_2O_5 (100% RRNP)	33.00^{c}	37.00^{e}	31.02^{ef}	35.50^{c}
Control	29.50^{d}	33.50^{f}	28.59^{f}	31.67^{d}
Significance	**	**	**	***
LSD (0.05)	2.69	1.12	2.45	2.76
CV (%)	6.50	6.30	6.30	6.30

Means followed by the same letter within a column are not significantly different at 5% level of significance; FYM = Farm Yard Manure, RRNP = Recommended Rate of Nitrogen and Phosphorus

The increment in thousand grain weight in response to increased rates of both organic and inorganic fertilizers might be attributed to the availability of optimum nitrogen, phosphorus and other nutrients in FYM that might led to high mean thousand grain weight through facilitating leaf growth and photosynthetic activities, thereby increasing partitioning of assimilate to the storage organ. In consistent with this result, Kler *et al*. (2007) reported that thousand grain weight was significantly higher when 10 tons of FYM ha^{-1} with 80% of recommended mineral NP was applied on wheat.

Yields and harvest index

The main effect of variety and fertilizer management were significant ($p<0.01$) on the total aboveground dry biomass yield both in Adiyo and Ghimbo. Moreover, the interaction of fertilizer management and variety had shown significant ($P< 0.01$) effect on total aboveground dry biomass yield in Ghimbo and non significant in Adiyo. The interaction effect of variety with fertilizer management indicated that the maximum total above ground dry biomass yield of 7432.70 kg ha^{-1} in Ghimbo (Table 2) was obtained from the application of 5 t ha^{-1} FYM in combination with 75% recommended rate of inorganic NP for variety 'Diribe'. Also the main effect of fertilizer management in Adiyo indicated that the application of 5 t ha^{-1} FYM in combination with 75% recommended rate of inorganic NP resulted to the maximum total above ground dry biomass yield of 7507 kg ha^{-1} (Table 4).

Similarly, the total aboveground dry biomass was more in response to the application of increased NP and the combined application of FYM with different rates of inorganic NP as compared to that of 100% recommended rate of NP fertilizer and control. This might have resulted from improved root growth and increased uptake of nutrients favouring better growth of the crop because of improved soil conditions as a result of applied fertilizers. In comparison to increased rates of inorganic nitrogen and phosphorus, the combined application of 5 t FYM with 25, 50 and 75% recommended rates of NP resulted in higher total aboveground dry biomass yield at both sites. The superiority of FYM over inorganic NP fertilizer might be due to more favourable effect of FYM on soil aggregation resulting in better physical condition such as bulk density and water holding capacity of the soil. This result was in agreement with Negi and Mahajan (2000) who had reported significant increase in wheat aboveground dry biomass yield with the addition of 8 t ha^{-1} FYM with 50% recommended inorganic NP. Improvement in the barley biomass yield has a positive contribution for farmers in the study areas where mixed crop-livestock farming is predominant as it increases availability of livestock feed in dry seasons.

Grain yield is the outcome of collective contribution of different yield components, which can be affected by various growing conditions and crop managing practices. The analysis of variance indicated that the main effect of variety and fertilizers significantly ($P < 0.01$) affected grain yield, while their interaction was not significant at both sites.

Variety 'GABULA' gave significantly higher grain yield of 2409 kg ha^{-1} in Adiyo and 2255 kg ha^{-1} in Ghimbo which could be attributed to higher number of effective tillers, number of grains per spike and thousand kernels weight.

With regards to the main effect of fertilizer, the highest grain yield of 2899 kg ha^{-1} in Adiyo and 2581 kg ha^{-1} at Ghimbo were obtained with the application of 5 t ha^{-1} FYM + 75% recommended NP rate followed by 5 t ha^{-1} FYM + 50% recommended NP rate which showed a statistically non significance difference with 5 t ha^{-1} FYM + 25% inorganic NP (Table 4). The higher yields from the combined application of FYM with mineral fertilizers could be attributed to the continuous supply of nutrients throughout the developmental stages of the crop.

The application of 100% recommended rate of NP (23 kg N ha^{-1} + 46 kg P_2O_5 ha^{-1}) alone resulted in lower grain yield at both sites when compared to either of the integrated application of FYM with inorganic NP fertilizers or the application of increased rates of nitrogen and phosphorus fertilizers. Similarly, Khalid *et al*., (2011) reported that the application of 8 t ha^{-1} FYM with 50% recommended rate of inorganic NP has resulted in 88% and 55% yield advantage of wheat over the control and the application of 100% recommended NP fertilizer rate alone, respectively.

This study result was in line with that of Lorry *et al.* (2006) who reported that the application of mineral fertilizers rapidly releases nutrients during the early growth stages and the organic fertilizer release nutrients gradually up to the later developmental stages. Haile *et al.,* (2012) reported that nutrients supplies to the crops are synchronized with all growth stages in accordance with plant demand. The result also agrees with Tiessen *et al.,* (1994) who attributed the increase in grain yield of barley as a result of the combined application of FYM and mineral NP to improvement in soil organic matter which is a determinant of soil fertility.

Table 4. The main effect of variety and fertilizer application on grain yield (GY), aboveground biomass yield (AGBY) and harvest index (HI) of barley in Adiyo and grain yield (GY) and harvest index (HI) of barley at Ghimbo, Southwestern Ethiopia in 2014

Factor	Adiyo			Ghimbo	
	GY (kg ha^{-1})	AGBY (kg ha^{-1})	HI (%)	GY (kg ha^{-1})	HI (%)
Variety					
GABULA	2409.00^{a}	6102.00^{a}	39.26^{a}	$2255..00^{a}$	38.02^{a}
Diribe	2200.00^{b}	5838.00^{b}	37.11^{b}	$1925..00^{b}$	37.15^{b}
Significance	**	**	*	**	**
LSD (0.05)	87.90	132.50	1.14	63.50	0.82
Fertilizer					
2.5 t ha^{-1} FYM + 50% RRNP	2116.00^{f}	5130.00^{g}	41.50^{ab}	1875.00^{e}	37.83^{c}
2.5 t ha^{-1} FYM + 75% RRNP	2425.00^{de}	6310.00^{e}	38.38^{c}	2126.00^{d}	37.87^{bc}
5 t ha^{-1} FYM + 25% RRNP	2706.0^{abc}	7052.00^{bc}	38.78^{bc}	2396.00^{bc}	37.85^{c}
5 t ha^{-1} FYM + 50% RRNP	2761.00^{ab}	7323.00^{ab}	38.70^{bc}	2575.00^{a}	37.14^{c}
5 t ha^{-1} FYM + 75% RRNP	2899.00^{a}	7507.00^{a}	37.55^{c}	2581.00^{a}	37.80^{c}
46 kg ha^{-1} N + 69 kg ha^{-1} P_2O_5	2139.00^{f}	5542.00^{f}	38.55^{c}	1875.00^{e}	37.80^{c}
69 kg ha^{-1} N + 46 kg ha^{-1} P_2O_5	2208.00^{ef}	5566.00^{f}	39.59^{abc}	2065.00^{d}	39.95^{ab}
69 kg ha^{-1} N + 69 kg ha^{-1} P_2O_5	2431.00^{de}	5776.00^{f}	42.05^{a}	2130.00^{d}	41.50^{a}
92 kg ha^{-1} N + 23 kg ha^{-1} P_2O_5	2494.00^{cd}	6302.00^{e}	39.46^{abc}	2298.00^{c}	38.95^{bc}
92 kg ha^{-1} N + 46 kg ha^{-1} P_2O_5	2612.0^{bcd}	6576.00^{de}	39.23^{abc}	2475.00^{ab}	37.91^{bc}
92 kg ha^{-1} N + 69 kg ha^{-1} P_2O_5	2666.00^{bc}	6854.00^{cd}	38.76^{bc}	2491.00^{ab}	38.19^{bc}
23 kg ha^{-1} N + 46 kg ha^{-1} P_2O_5 (100% RRNP)	1751.00^{g}	5120.00^{g}	34.20^{d}	1614.00^{f}	33.62^{d}
Control	751.00^{h}	2550.00^{h}	29.62^{e}	670.00^{g}	32.13^{d}
Significance	**	**	**	**	**
LSD (0.05)	224.20	337.80	2.92	162.00	2.09
CV (%)	8.40	4.90	6.60	6.70	4.80

Means followed by the same letter within a column are not significantly different at 5% level of significance; * FYM = Farm Yard Manure, RRNP = Recommended Rate of Nitrogen and Phosphorus

Similarly, Acharya *et al.*, (2007) reported that high rainfall intensity and steep slope nature of the land caused nutrient depletion and decreased crop productivity.

The main effect of variety and fertilizer significantly (P<0.05) affected the harvest index of the crop. Accordingly, variety 'GABULA' had significantly higher harvest index of 39.26% in Adiyo and 38.02% in Ghimbo (Table 4).

Similarly, the highest harvest index of 42.05% in Adiyo and 41.50% in Ghimbo were obtained with the application of 69 kg N ha^{-1} in combination with 69 kg P_2O_5 ha^{-1} (Table 4). The result of this study indicated that the application of either increased rate of FYM in combination with increased rates of NP or the combined application of increased rates of NP decreased harvest index when compared to other yield components and yield of barley. In line with this result, Hossain *et al.* (2010) indicated that the increased N had a marked negative effect on harvest index of rice due to the fact that growth promoted by N application resulted in low harvest index by favoring more dry matter accumulation in the vegetative part rather than in the rice grain.

Grain, straw and total plant N and P uptake of barley

The result of the analysis showed that main effects of variety and fertilizers had significant (P < 0.01) effect on the grain, straw and total plant N uptake at both sites. However, the interaction effect of variety and fertilizer was significant (P< 0.05) for straw N uptake only at both sites. Variety 'GABULA' had significantly higher grain N uptake of 24.37 kg ha^{-1} in Adiyo and 24.42 kg ha^{-1} in Ghimbo. The N uptake by plant (grain + straw) indicated that the highest N uptake of 39.75 kg ha^{-1} in Adiyo and 38.50 kg ha^{-1} in Ghimbo was recorded for 'GABULA' variety (Table 5). Similarly the main effect of fertilizer indicated that the highest grain N uptake of 30.95 kg ha^{-1} in Adiyo and 30.74 kg ha^{-1} in Ghimbo was recorded with the application of 5 t ha^{-1} FYM + 75% recommended NP rate while for plants (grain + straw) the highest N uptake of 49.51 kg ha^{-1} in Adiyo and 49.01 kg ha^{-1} in Ghimbo was from the combined application of 5 t ha^{-1} FYM + 75%recommended NP rate which was at par with 5 t ha^{-1} FYM + 50% recommended NP . The highest uptake of N by grain in the combined application of FYM with NP could be of the main reason for producing highest grain yield at both sites.

Similarly, the straw N uptake indicated that the highest N uptake (20.19 kg ha^{-1}) by variety 'Diribe' in Adiyo and 21.66 kg ha^{-1} by variety 'GABULA' in Ghimbo were from the combined application of 92 kg ha^{-1} N with 69 kg ha^{-1} phosphorus rates and the application of 5 t ha^{-1} FYM + 50% recommended rate of inorganic NP respectively (Table 6).

The increased uptake of N by grain, straw and total plant at increased

FYM and inorganic NP fertilizer rates could be due to that FYM releases more nutrients through time, so that nutrient loss is less which might have resulted in more plant uptake. Moreover, it could be due to the balanced and steady supply of nutrients to plants at all stage of crop growth. Application of FYM might have improved the physical condition of the soil and helped in absorption and translocation of nutrients from the soil. The application of inorganic NP in combination with FYM is known to improve various soil physico-chemical properties like water holding capacity, porosity, soil organic carbon, total N etc. resulting in enhanced nutrient absorption or uptake (Pandey *et al.,* 2007). In general, there was a significant increase in N uptake by grain, straw or total plant from the control to the highest N uptake by grain, straw and total plant at both sites. The reason for this wide range could be that fertilizer nutrient at lower level might be lost by volatilization of ammonia from urea and the amount of loss varies with soil conditions and nutrient sources. It is commonly believed that the combination of FYM and inorganic fertilizer increases synchrony and reduce nutrient losses by converting inorganic nitrogen into organic forms hence increases N uptake by crops and is important in enhancing the efficiency of the fertilizer (Kramer *et al*., 2002). Significant difference ($P < 0.001$) was observed on P uptake by grain, straw and total plant (grain + straw) due to the main effect of fertilizers and varieties both in Adiyo and Ghimbo. The interaction effect of variety and fertilizer was significant on grain and straw P uptake, but non-significant on total plant (grain + straw) P uptake. Accordingly, the highest grain P uptake of 19.11 kg ha^{-1} in Adiyo and 20.31 kg ha^{-1} in Ghimbo were observed for variety 'Diribe' with the application of 5 t ha^{-1} FYM + 75% recommended rate of inorganic NP (Table 6).

It was also observed that the application of 92 kg N ha^{-1} combined with 69 kg P_2O_5 ha^{-1} resulted in the highest straw P uptake (9.50 kg ha^{-1}) by variety 'GABULA' in Ghimbo and the application of 5 t ha^{-1} FYM + 75% recommended rate of inorganic NP resulted to the highest straw P uptake (11.11 kg ha^{-1}) by variety 'Diribe' in Adiyo (Table 6).

Table 5. The main effect of variety and fertilizer application on nitrogen and phosphorus uptake by grain and whole plant of barley at Adiyo and Ghimbo, Southwestern Ethiopia in 2014

Factor	Adiyo			Ghimbo		
	NUG (kg ha^{-1})	NUP (kg ha^{-1})	PUP (kg ha^{-1})	NUG (kg ha^{-1})	NUP (kg ha^{-1})	PUP (kg ha^{-1})
Variety						
GABULA	24.37^{a}	39.75^{a}	19.10^{b}	24.42^{a}	38.50^{a}	18.52^{b}
Diribe	23.09^{b}	37.45^{b}	21.87^{a}	20.83^{b}	33.00^{b}	20.00^{a}
Significance	**	*	**	**	*	**
LSD (0.05)	0.62	0.83	0.86	1.24	1.49	0.63
Fertilizer						
2.5 t ha^{-1} FYM + 50% RRNP	20.75^{g}	32.67^{f}	17.14^{ef}	20.59^{d}	29.59^{fg}	16.64^{e}
2.5 t ha^{-1} FYM + 75% RRNP	22.47^{ef}	36.73^{e}	20.18^{cd}	21.61^{cd}	35.22^{c-f}	19.14^{d}
5 t ha^{-1} FYM + 25% RRNP	26.60^{bc}	42.13^{c}	24.89^{b}	25.55^{b}	39.65^{cd}	22.44^{bc}
5 t ha^{-1} FYM + 50% RRNP	26.70^{bc}	44.63^{b}	25.57^{ab}	30.74^{a}	49.01^{a}	24.71^{a}
5 t ha^{-1} FYM + 75% RRNP	30.95^{a}	49.51^{a}	27.11^{a}	29.15^{a}	47.57^{ab}	25.45^{a}
46 kg ha^{-1} N + 69 kg ha^{-1} P_2O_5	22.00^{fg}	34.02^{f}	15.63^{f}	20.05^{d}	30.20^{efg}	16.77^{e}
69 kg ha^{-1} N + 46 kg ha^{-1} P_2O_5	24.04^{de}	38.15^{de}	18.67^{de}	21.97^{cd}	33.79^{def}	18.49^{d}
69 kg ha^{-1} N + 69 kg ha^{-1} P_2O_5	25.39^{cd}	39.98^{d}	21.20^{c}	23.76^{bc}	36.68^{cde}	19.51^{d}
92 kg ha^{-1} N + 23 kg ha^{-1} P_2O_5	26.11^{bc}	44.20^{bc}	23.65^{b}	24.27^{bc}	39.22^{cd}	21.24^{c}
92 kg ha^{-1} N + 46 kg ha^{-1} P_2O_5	26.29^{bc}	44.64^{b}	24.70^{b}	25.94^{b}	40.20^{cd}	21.82^{bc}
92 kg ha^{-1} N + 69 kg ha^{-1} P_2O_5	27.16^{b}	45.76^{b}	25.80^{ab}	25.98^{b}	41.79^{bc}	22.95^{b}
23 kg ha^{-1} N + 46 kg ha^{-1} P_2O_5 (100% RRNP)	17.53^{h}	29.87^{g}	14.98^{f}	15.01^{e}	26.57^{g}	14.65^{f}
Control	12.47^{i}	19.53^{h}	6.81^{g}	9.52^{f}	15.23^{h}	6.55^{g}
Significance	**	**	*	**	*	**
LSD (0.05)	1.59	2.12	2.21	2.51	3.79	1.61
CV%	5.80	4.70	9.30	12.10	9.20	7.20

Means followed by the same letter within a column are not significantly different at 5% level of significance; * FYM = Farm Yard Manure, RRNP = Recommended Rate of Nitrogen and Phosphorus; NUG = Nitrogen Uptake of Grain; NUP = Nitrogen Uptake of Plant (grain + straw); PUP = Phosphorus Uptake of Plant (grain + straw)

The nutrient uptake by the crop is determined by its nutrient contents and yield and apparently yield was a more vital deciding factor for the uptake of nutrients by the crop. In agreement to this result, Ibrahim *et al*. (2008) reported that the N and P uptake of wheat were increased by the combination of inorganic NP with increased rates of farm yard manure.

The application of 5 t ha^{-1} FYM + 75% recommended rate of inorganic NP resulted in the highest P uptake by total plant (grain + straw) of 27.11 kg ha^{-1} and 25.45 kg ha^{-1} in Adiyo and Ghimbo, respectively (Table 5). The highest P uptake obtained from FYM applied plots could be attributed to the increased P availability and increased root growth of the crop.

Table 6. The interaction effect of variety and fertilizer application on straw N uptake (kg ha^{-1}), grain and straw P uptake (kg ha^{-1}) of barley at Adiyo and Ghimbo, southwestern Ethiopia in 2014

Variety	Fertilizer management	Adiyo			Ghimbo		
		Straw N uptake	Grain P uptake	Straw P uptake	Straw N uptake	Grain P uptake	Straw P uptake
GABULA	2.5 t ha^{-1} FYM + 50% RRNP	11.66^{ij}	10.66^{i}	4.33^{h-k}	9.00^{jk}	10.66^{i}	4.33^{gh}
	2.5 t ha^{-1} FYM + 75% RRNP	14.33^{fgh}	13.66^{fgh}	6.33^{e-h}	15.00^{b-e}	14.00^{gh}	5.00^{fg}
	5 t ha^{-1} FYM + 25% RRNP	15.00^{efg}	16.33^{b-e}	8.33^{b-e}	14.00^{d-f}	14.66^{e-h}	7.00^{bcd}
	5 t ha^{-1} FYM + 50% RRNP	18.66^{abc}	16.66^{bcd}	6.33^{e-h}	21.66^{a}	16.00^{def}	7.33^{bc}
	5 t ha^{-1} FYM + 75% RRNP	20.00^{a}	17.00^{bc}	7.00^{d-g}	21.33^{a}	16.33^{cde}	8.00^{b}
	46 kg ha^{-1} N + 69 kg ha^{-1} P_2O_5	10.00^{j}	12.33^{ghi}	3.66^{j-l}	10.00^{ij}	13.00^{h}	3.33^{h-k}
	69 kg ha^{-1} N + 46 kg ha^{-1} P_2O_5	13.00^{ghi}	14.00^{fg}	4.00^{i-l}	12.33^{f-i}	13.00^{h}	3.00^{ijk}
	69 kg ha^{-1} N + 69 kg ha^{-1} P_2O_5	13.00^{ghi}	14.66^{ef}	5.33^{g-j}	12.66^{e-h}	13.00^{h}	5.66^{ef}
	92 kg ha^{-1} N + 23 kg ha^{-1} P_2O_5	17.00^{b-e}	14.00^{fg}	9.00^{a-d}	16.66^{bc}	14.33^{fgh}	6.66^{cde}
	92 kg ha^{-1} N + 46 kg ha^{-1} P_2O_5	17.67^{a-d}	14.00^{fg}	9.00^{a-f}	15.33^{bcd}	14.00^{gh}	7.33^{bc}
	92 kg ha^{-1} N + 69 kg ha^{-1} P_2O_5	17.00^{b-e}	14.33^{f}	9.50^{a-d}	17.33^{b}	14.00^{gh}	9.50^{a}
	23 kg ha^{-1} N + 46 kg ha^{-1} P_2O_5 (100% RRNP)	12.33^{hij}	8.66^{j}	4.00^{i-l}	11.00^{g-j}	8.00^{i}	5.00^{fg}
	Control	7.00^{k}	3.10^{l}	2.06^{l}	6.66^{kl}	3.03^{l}	2.56^{jk}
Diribe	2.5 t ha^{-1} FYM + 50% RRNP	12.16^{hij}	14.22^{f}	5.06^{g-k}	9.00^{jk}	15.22^{efg}	3.06^{h-k}
	2.5 t ha^{-1} FYM + 75% RRNP	14.20^{f-i}	14.29^{f}	6.07^{f-i}	12.22^{f-i}	16.18^{de}	3.10^{h-k}
	5 t ha^{-1} FYM + 25% RRNP	16.06^{c-f}	17.07^{bc}	8.03^{c-f}	14.18^{c-f}	18.07^{bc}	4.80^{fg}
	5 t ha^{-1} FYM + 50% RRNP	17.18^{b-e}	18.03^{ab}	10.10^{abc}	15.21^{b-e}	20.29^{a}	5.80^{def}
	5 t ha^{-1} FYM + 75% RRNP	17.11^{b-e}	19.11^{a}	11.11^{a}	15.17^{b-e}	20.30^{a}	6.60^{cde}
	46 kg ha^{-1} N + 69 kg ha^{-1} P_2O_5	14.03^{f-i}	12.18^{hi}	3.07^{kl}	10.29^{hij}	14.0^{gh}	3.20^{h-k}
	69 kg ha^{-1} N + 46 kg ha^{-1} P_2O_5	15.22^{d-g}	15.22^{def}	4.11^{i-l}	11.29^{g-j}	15.18^{efg}	3.80^{g-j}
	69 kg ha^{-1} N + 69 kg ha^{-1} P_2O_5	16.18^{c-f}	15.22^{def}	7.18^{d-g}	13.17^{d-g}	16.15^{def}	4.20^{ghi}
	92 kg ha^{-1} N + 23 kg ha^{-1} P_2O_5	19.18^{ab}	16.22^{b-e}	8.07^{c-f}	13.22^{d-g}	17.28^{bcd}	4.20^{ghi}
	92 kg ha^{-1} N + 46 kg ha^{-1} P_2O_5	19.04^{ab}	17.29^{bc}	9.10^{a-d}	13.18^{d-g}	18.20^{b}	4.11^{ghi}
	92 kg ha^{-1} N + 69 kg ha^{-1} P_2O_5	20.19^{a}	17.32^{bc}	10.44^{ab}	14.29^{c-f}	18.17^{b}	4.23^{e-h}
	23 kg ha^{-1} N + 46 kg ha^{-1} P_2O_5 (100% RRNP)	12.33^{hij}	12.07^{hi}	5.22^{g-k}	12.11^{f-i}	13.11^{h}	3.20^{h-k}
	Control	7.12^{k}	4.98^{k}	3.46^{j-l}	4.76^{l}	5.40^{k}	2.10^{k}
Significanc		**	*	**	**	**	**
LSD (0.05)		2.60	1.75	2.19	2.57	1.83	1.30
CV (%)		10.70	7.70	10.50	12.00	7.80	6.30

Means followed by the same letter within a column are not significantly different to each other at P = 0.05 level of significance; * FYM = Farm Yard Manure, = Recommended Rate of Nitrogen and Phosphorus

In line with this result, Aziz *et al.*, (2010) reported that root growth in plants receiving FYM was higher and hence would increase nutrient uptakes. Yassen *et al.*, (2010) further suggested that FYM application increased the movement of elements between the solid phase and soil solution which could also be a reason for the highest nutrient uptakes. The increased activity of soil microorganisms under higher FYM applications might have also increased nutrient uptake (Yassen *et al.*, 2010). This result was also in agreement with that of Hossain *et al*. (2010) who reported higher N and P uptakes in rice with FYM application over control and inorganic fertilizers alone.

On the other hand, the uniform and sufficient rainfall during the study period might have also enhanced activity of soil organisms so as to accelerate organic matter decomposition and nutrient mineralization, thereby more availability for plant uptake.

Similarly, Rakul and Anje (2011) reported that integrated application of FYM and inorganic NP improved soil fertility and NP uptake by wheat and increased the yield where the application of 8 t ha^{-1} FYM and 40% recommended rate of NP increased the yield of wheat through optimization of soil fertility and increasing NP uptake both by grain and straw. Hence, integrated use of FYM reduces the use of inorganic NP, restore organic matter in soil, enhance nutrient use efficiency of crops and maintain soil quality in terms of physical, chemical and biological properties.

Conclusion

The results of the study showed that variety 'GABULA' had significantly higher thousand grain weight, number of grain $spike^{-1}$, number of productive tillers m^{-2}, total aboveground dry biomass yield and grain yield. Similarly, among the fertilizer treatments, the application of 5 t FYM ha^{-1} combined with 75% recommended rate of inorganic NP had significantly the highest thousand grain weight, total above ground dry biomass yield and grain yield. Moreover, the application of 5 t ha^{-1} FYM combined with 75% inorganic NP has resulted in the highest grain, straw and total plant uptake of both N and P over the other treatments. Therefore, the application of 5 t ha^{-1} FYM in combination with 75% inorganic NP fertilizer on variety 'GABULA' can increase the productivity of barley in the study areas. Thus, integrated application of FYM and inorganic N and P can ensure more supply of barley biomass as a feed resource particularly during the dry season. On top of being a feed of high value for livestock, the straw can be utilized in plastering of walls and thatching of house construction.

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