Response of Barley and Faba Bean to Application of Litter-Wood Ash Mixture in the Central Highlands of Ethiopia

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Abstract

Each household at the rural areas of central highlands of Ethiopia produces ash and house refuse mixtures almost every day and gather it near the homestead. The stockpile of litter-wood ash material is one of the locally available soil replenishing resources used by the farmers. The study assessed the importance, extent and use of litter-wood ash as a source of fertilizer to cereal and pulse crops. Initially, the study was conducted as an on-station experiment with solely/pure ash rates then the treatments rates and type of ash were modified according to the farmers' practice of litter-wood ash. The experiment was conducted at Mush and Atakilt on farmers' field permanently for 4 years. The treatments used for the on-farm experiment were control, 3 litter ash treatments (11, 22, and 44 t ha $^{-1}$) and a recommended chemical fertilizers for barley and faba bean and replicated 3 times. The study showed that many farmers do believe ash materials have the potential to amend soil conditions and replenish soil for the crop. the rates of litter-wood ash used by the farmers varies depending on the availability of litter-wood ash mixture in the farmstead, the inherent soil fertility status of the farmland and the crop type to be fertilized. Results showed that significantly higher faba bean and barley yields were obtained from the use of 1 t ha^{-1} and 22 t ha^{-1} of litter-wood ash applied at every 2 years period. Litter-wood ash could be used as the best soil amendment material that adds plant nutrients to the soil. If managed properly, litter-wood ash could be sustainable alternative to agricultural lime, with many economic and environmental benefits. Since ash has low density and small particle size, it is necessary to avoid spreading it on very dry and windy days as well as on waterlogged conditions. Hence, farmers should be advised to store their litter-wood ash mixtures away from runoff and avoid its application immediately after prolonged rainfall.

Key words: Litter-wood ash, Sole ash, Barley, Faba Bean

Introduction

Agricultural production in the highlands of Ethiopia is limited by many factors, including nutrient deficiencies and soil acidity. To overcome these problems, crop producers utilize different farming practices and apply fertilizers. Organic fertilizer represents the cheapest and most sustainable option for crop producers. Among organic fertilizers, farm yard manure (FYM) offers an affordable and readily available plant nutrient to the plant, build up the fertility status of the soil and eventually improves the soil structure.

Litter-wood ash mixture is inorganic and organic residue remaining after the combustion of wood or unbleached wood fibers mixed with house refuses. This ash has been considered as a waste product instead of a resource as few industries have taken advantage of the beneficial properties of the ash. Today, several million tons of wood ashes are produced annually in the world. In most developed countries wood ash is produced by pulp and paper mills from the incineration of hog fuel that consists of waste wood, knots, and barks. Agronomic benefits resulting from land application of pulp and paper mill by-products such as biosolids from effluent treatment systems or wood ash from energy systems have been widely studied in Europe (Karsisto, 1979), the United States (Vance, 1996; Mitchell and Black, 1997), and more recently in Canada (Lickacz, 2002). For centuries, farmers have recycled wood ash during the clearing of forests to increase arable lands. As a result, yields in these cleared areas often increased because of ash-induced changes in soil pH and chemical composition (Hopkins, 1910; Giovannini *et al.*, 1993). Many of these developed countries are utilizing wood ash as a soil amendment material and this has been documented. Applications of ash at rates of less than 50 t ha^{-1} in greenhouse and field studies increased dry matter yield in oat (*Avena sativa* L.) (Krejsl and Scanlon, 1996), wheat (*Triticum aestivum* L.) (Etiegni *et al.,* 1991; Huang *et al.,* 1993), bean (*Phaseolus vulgaris* L.) (Krejsl and Scanlon, 1996), barley (*Hordeum vulgare* L.), alfalfa (*Medicago sativa* L.) (Meyers and Kopecky, 1998) and some forage crops (Naylor and Schmidt, 1989; Muse and Mitchell, 1995; Meyers and Kopecky, 1998).

The rural people in least developed countries like Ethiopia are using bulk of wood and cattle dung as source of energy and sources of cash income. Each household at the rural areas of central highlands of Ethiopia produces ash and house refuse mixtures almost every day and gather it near the homestead. This stockpile of litter-wood ash material is one of the locally available soil replenishing resources used by the farmers. However, in some areas, farmers do not want to collect the ash near their houses. Most farmers, particularly female farmers, have been using litter-wood ash as a fertilizer and spread it under vegetables and some other garden plants. Beyond the old soil burning or 'gai' practices, farmers in North Shewa (Baso, Angolelana Asagirt, Sheno and Hagere Mariam) have long tradition of applying litter-wood ash mixture to their farmlands. Farmers are applying litter-wood ash mixtures to their farmlands in particular in heavy Vertisols. Usually the litter ashes are being applied in a week or two weeks time before cropping. Sometimes these ashes are mixed with small amount of FYM and form manured ash. However, neither field nor greenhouse studies were conducted with regard to the use of ash as soil amendment material under varieties of crops. In order to support or nullify such a practice, there need to be research based information. Hence, the purpose of this study was to assess and understand the extent and use of ash as a fertilizer source in selected areas of North Shewa, and to investigate the effect of ash on yield and yield components of barley and faba bean.

Material and Methods

A survey and two field experiments were carried out in two phases: The first study was conducted on station with solely ash (ash free of unburned or bleached materials), while the second study was conducted on farm with litter/wood-ash mixture (the actual farmers practice) sampled from farmers' ash stockpiles. In Phase I of this study, the extent and use of litter ash as a soil amendment material was assessed and first hand information from group of farmers at different locations was compiled. The application rates of ash and the general information gathered from the farmers were quantified in the field during main cropping season. Further, designed field experiment on the effect of ash on barley yield and yield components was conducted for one year. The on-station field experiment was carried out to evaluate four rates of solely ash (4.7, 9.4, 14, and 21 t ha^{-1} on dry weight base), 41/46 kg ha^{-1} N/P_2O_5 as Urea and DAP, and control (without ash and fertilizer) for two cropping seasons. The experiment was laid out in randomized complete block factorial design with 4 replications. The experimental field was made to have broad bed and furrows (BBF) to drain excess water. . The survey data was displayed with descriptive statistics, while the data from the field experiment was subjected to statistical analyses.

In Phase II**, a**fter conducting the on-station experiment, it was realized that the actual ash type used as soil amendment/fertilizer sources by farmers was not solely ash material, but it was rather litter-wood ash mixtures. Hence, the on-farm experiment was conducted in a more practical and rational way with litter-wood ash mixtures used by the farmers. The litter-wood ash used for the study was collected from representative farmers' homestead in Mush and Keyit areas. A sample was taken from the collected material for chemical and physical analyses in the laboratory. The treatments for field experiments were formulated based on the laboratory data and the information generated from the 1st phase of this study. The experimental design used in the study was split plot with four replications. Two application times (Once and twice in every two years applications) as main-plot treatments and five ash application rates (Control, 11 tons ha^{-1} litter-wood ash, 22 tons ha^{-1} litter-wood ash, 44 ton ha^{-1} litter-wood ash, and 21 tons ha^{-1} sole ash that were selected from the on station experiment and blanket recommendation of 41/46 and 18/46 kg ha^{-1} N/P_2O_5 as Urea and DAP for barley and faba bean, respectively were used as sub-plot treatments. The total experimental area used for the experiment was 1026 m^2. The test crops used for the field experiments were food barley and faba bean. The experiment was conducted in the same place for 4 years being each crop as a precursor crop for the other as practiced by the farmers, faba bean followed by barley. In both cases, planting was done in 2 weeks time after application of the litter-wood ash mixture to the field. The survey data was displayed in descriptive statistics, while the data from the field experiment was subjected to statistical analysis.

Results and Discussions

Farmers in Keyit, Mush, Angolela Asagirt and Hagere mariam woredas use high amounts of litter-wood ash alternatively under faba bean (*Vicia faba*), field pea and barley (*Hordeum vulgare* L.) crops.

Farmers knowledge on the use of ash

Fortified litter-wood ash mixture is one of the traditionally and commonly used organic fertilizers. Hence, a survey was conducted on the use and importance of ash as a soil amendment material by the farmers. Many farmers do believe that ash materials accumulated for a period of time would have the potential to amend soil condition as well as replenish soil for the improvement of crop growth. In the survey conducted at two locations, on average 21 – 25 farmers per group responded to the questions related on the use of ash as an input in agriculture. According to the farmers, the application of wet litter-wood ash reaches approximately 8 - 12.8, 17.9 - 33.2, 33.3 - 60.6 t ha^{-1} respectively, is practiced by the poor, medium and rich (based on their livestock wealth) farmers. The study showed that the approximate rate of litter-wood ash application ranges from 3.1 – 5.2 and 7.8 – 19.6 t ha^{-1} (on 6% moisture level bases) at Keyit and Mush areas, respectively (Table 1).

Table 1. Approximate farmers' usage of litter-wood ash and estimated labor required for its distribution around Debre Birhan, North Shewa, 1999.

Site	Farmers' land size (m^2)	Group of Respo ndent	Approximate use of ash per ha. (on dry wt. basis), (tones) Min	Max	Average Min	Average Max	Labor required for ash distribution. Man-days/land size	Number of donkeys used for ash transportation per farm size
Mush	782	GI	9.6	16.8	8.4	15.6	15	20
		GII	7.2	14.4			15	20
Mush	400	GI	1.4	23.5	13.3	19.6	4	10
		GII	1.3	15.6			4	10
Mush	440	GI	8.5	12.8	7.8	14.2	5	12
		GII	10.7	17.1			6	15
		GIII	4.3	12.8			2	20
Keyit	400	GI	3.8	5.2	3.7	5.2	-	-
	3250	GI	3.1	4.1	3.1	4.0	-	55

GI, GII and GIII -- Group of farmers

In fact, these rates vary from farmer to farmer depending on the availability of litter-wood ash mixture in the farmstead and the inherent soil fertility status of the farmland. Unfortunately, barley fields that are treated with litter-wood ash are usually exposed to high weed infestation. Therefore, farmers are expected to weed their crop fields on time. Moreover, such a practice requires quite high donkey and human labor, for ash transportation and distribution on farmlands.

Effect of pure ash on yield of barley and faba bean

Prior to the onfarm litter-wood ash experiment an on-station experiment was conducted using pure wood ash (solely ash) as a soil amendment material.

Thus the study showed that the barley yields obtained were significantly different among the different pure ash rate treatments. The on-station field experiment showed that there were no significant barley grain yield difference ($P<0.05$) between two solely ash rates (14 and 21 tons ha^{-1}) and these ash treatments gave very comparable grain yield with that of the recommended chemical fertilizer rate (41/46 N/P_2O_5). The grain yields obtained from the above two treatments ($\geq$1.0 tons ha^{-1}) were more than double of the grain yield obtained from control treatment (0.5 t ha^{-1}) (Table 2). The yield increments from these treatments were 124, 158 and 165.5% over the control (Table 3). Barley plants grown with the applications of both the chemical fertilizer and solely litter-wood ash rates matured earlier than the control treatment. The mineral fertilizer and the three highest ash rates gave earlier days to heading (4 to 11 days prior) and better tillering capacity (Table 3). The solely ash treatments used on the on-station experiment showed significant impact on grain yield of barley.

Table 2. Grain yield, days to maturity, number of tillers and stand count of barley for solely applied ashes rates.

Treatments	Grain yield (t ha^{-1})	Biomass yield (t ha^{-1})	Straw yield (t ha^{-1})	Days to heading	Number of tillers	Plant stand count
Control (without ash/fertilizer)	0.5 c	1.7 b	1.2 b	83.00 a	4.38 d	56.00
4.7 t ha^{-1} solely ash	0.7 c	1.7 b	1.0 b	80.75 ab	5.75 cd	60.75
9.4 t ha^{-1} solely ash	0.8 bc	1.8 b	1.0 b	79.00 bc	6.75 bc	62.75
14 t ha^{-1} solely ash	1.0 ab	2.4 b	1.2 b	76.00 cd	6.75 bc	60.75
21 t ha^{-1} solely ash	1.3 a	2.6 b	1.3 b	74.00 de	7.63 b	66.75
41/46 kg ha^{-1} N/P_2O_5	1.3 a	3.8 b	2.4 a	71.50 e	9.88 a	65.00
CV (%)	26.34	28.14	40.98	2.71	15.16	19.72
$LSD_{0.05}$	0.39	0.98	0.83	3.16	1.57	NS

Table 3. Grain yield of barley obtained with the use of ash as a fertilizer

Treatments	Grain yield, t ha^{-1}	% Relative yield increment over the control
Control	0.51	--
4.7 t ha^{-1} solely ash	0.70	39.57
9.4 t ha^{-1} solely ash	0.84	65.84
14 t ha^{-1} solely ash	1.13	124.17
21 t ha^{-1} solely ash	1.31	158.40
41/46 kg ha^{-1} N/P_2O_5 (Urea/DAP)	1.34	165.58

We came to realize that there was clear variation between sole ash (used for the on station experiment) and litter-wood ash (used by the local farmers), the later being a justification to modify our treatments in the on-farm experiment discussed below. Results obtained from the on-farm experiment showed that both barley and faba bean considerable response to application of litter-wood ash rates for two alternative years. Despite the applied treatments, both barley and faba bean yields obtained from Atakilt area had poor performance in comparison with yields obtained from Mush. The overall combined barley grain, biomass and straw yields obtained from the two areas were illustrated in figure 1, 2 and 3 for barley and in figure 4, 5 and 6 for faba bean. The experiment on both barley and faba bean showed that all litter-wood ash and the chemical fertilizer treatments showed yield advantage over the control.

For ease of the reporting data obtained from each site were not presented here. With respect to the barley yield results obtained from the different ash rates at Atakilt area did not show significant yield differences ($P>0.05$). The 44 t ha^{-1} litter/wood-ash mixture was the only treatment that gave grain yield comparable with that of the recommended chemical fertilizer. Except 44 t ha^{-1} litter-wood ash, most ash treatments did not show grain yield advantage from the previous year litter-wood ash application. Similarly, the highest litter-wood ash (44 t ha^{-1}) showed the highest grain yield of barley over all the treatments at Mush area. In the second year the residual effect of 44 t ha^{-1} litter ash gave significantly different ($P<0.05$) grain yield advantage over the control and the rest of ash treatments. This indicates that in favorable environmental conditions like Mush, barley benefited from the left over plant nutrients applied in previous year.

Figure 1, 2 and 3 showed the results biomass, grain and straw yields obtained from the combined data analysis for the two sites. Barley biomass yield from litter-wood ash rate 22 t ha $^{-1}$ and over and straw yield from litter-wood ash rate 11 t ha $^{-1}$ and over applied every 2 years showed significantly different than application of the same rates every year (Figure 1 and 3). Contrary to the every 2 years application of litter-wood ash every year application of the chemical fertilizer gave better grain as well as straw yields. However, except for the straw yield there were no significant biomass and grain yield differences with the application of chemical fertilizer between the application periods. Due to the waterlogging problem occurred at Atakilt site the combined analysis did no clearly showed the impact of litter-wood ash on grain yield of barley. However, all litter-wood ash treatments showed a tendency to increase grain yield when applied every 2 years (Figure 2). Grain yield due to the every 2 year application of litter-wood ash at the rate of 22 t ha $^{-1}$ and over showed significant grain yield at Mush site. In the second year the residual effect of 44 t ha^{-1} litter ash gave significantly different ($P<0.05$) grain yield advantage over the control and the rest of ash treatments. Barley benefited from the left over litter-wood ashes applied in previous year. This suggests that farmers in Mush area do have the chance to use litter ash in alternate years (minimum 2 years). During the study period for all measured parameters of barley, the chemical fertilizer and the two highest litter-wood ash treatments responded better than the sole ash treatments. Every 2 years application of the solely/pure ash treatment showed significant biomass and straw yield differences (Figure 1 and 3). All litter-wood ash, solely ash and chemical fertilizer sources showed significant yield advantage over the control during both fertilizer application periods.

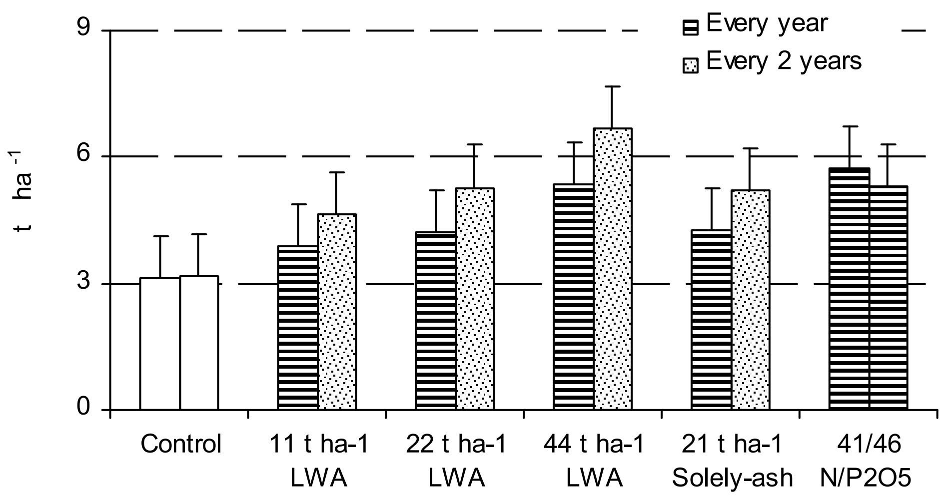

Figure 1. Barley biomass yield obtained from the use of litter-wood ash (with 2 application periods) and chemical fertilizer (with every year application)

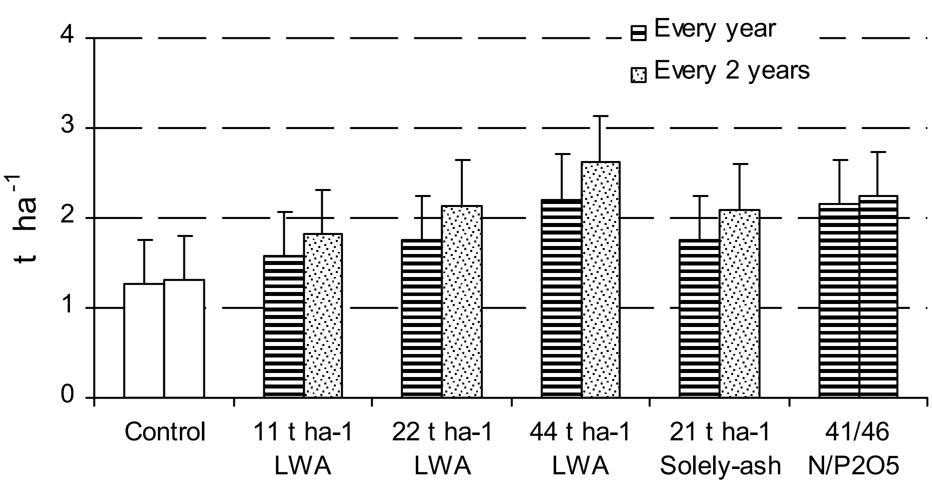

Figure 2. Barley grain yield obtained from the use of litter-wood ash (with 2 application periods) and chemical fertilizer (with every year application)

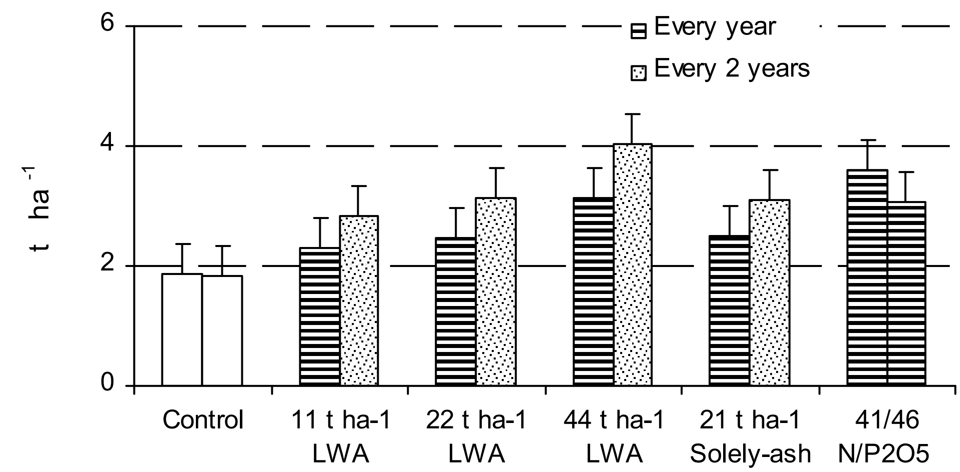

Figure 3. Barley straw yield obtained from the use of litter-wood ash (with 2 application periods) and chemical fertilizer (with every year application)

The overall faba bean yield obtained during the study period showed significant seed yield difference for both Atakilt and Mush locations ($P<0.05$). However, the coefficient of variation for the Atakilt area (43.05%) was very much higher than the Mush area (11.7%). Similar to the barley yield, due to waterlogging problem the Atakilt site was not conducive for the production of faba bean. Nevertheless, the combined data analysis for the 2 sites showed that biomass yield of faba bean was significant with every 2 years application of litter-wood ash at 11 t ha $^{-1}$ and over (Figure 4). However, litter-wood ash at the rate of 44 t ha $^{-1}$ and over did not show significant yield advantage for the two application periods. The minimum rates of litter ash to get the seed yield advantage were 11 and 22 t ha $^{-1}$, for at Atakilt and Mush area, respectively. Twenty two to 44 t ha $^{-1}$ litter-wood ash gave the best yield across the sites for all measured parameters of faba bean. The solely ash and litter-wood ash treatments did not show significant seed yield difference at $P>0.05$ level. The combined data analysis for faba bean did not show significant seed yield difference. At both locations faba bean might not utilized the applied chemical fertilizer properly. In all occasions the chemical fertilizer gave significantly low faba bean yields than the litter-wood ash treatments.

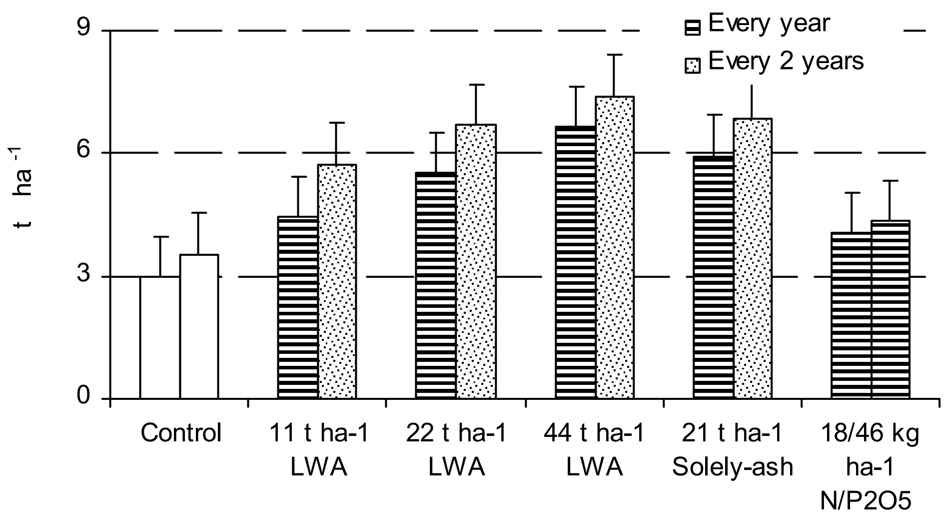

Figure 4. Faba bean biomass yield obtained from the use of litter-wood ash (with 2 application periods) and chemical fertilizer (with every year application). LWA (Litter-wood ash)

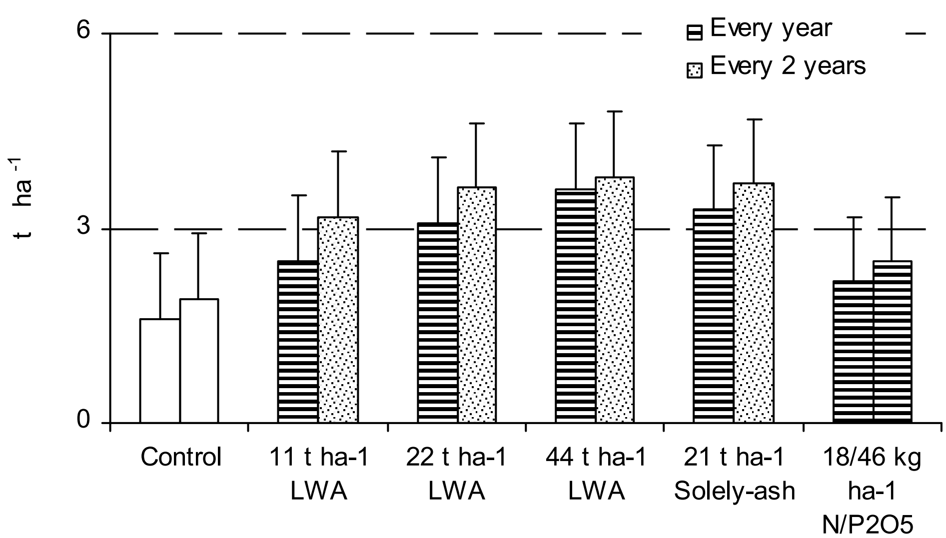

Figure 5. Faba bean biomass yield obtained from the use of litter-wood ash (with 2 application periods) and chemical fertilizer (with every year application). LWA (Litter-wood ash)

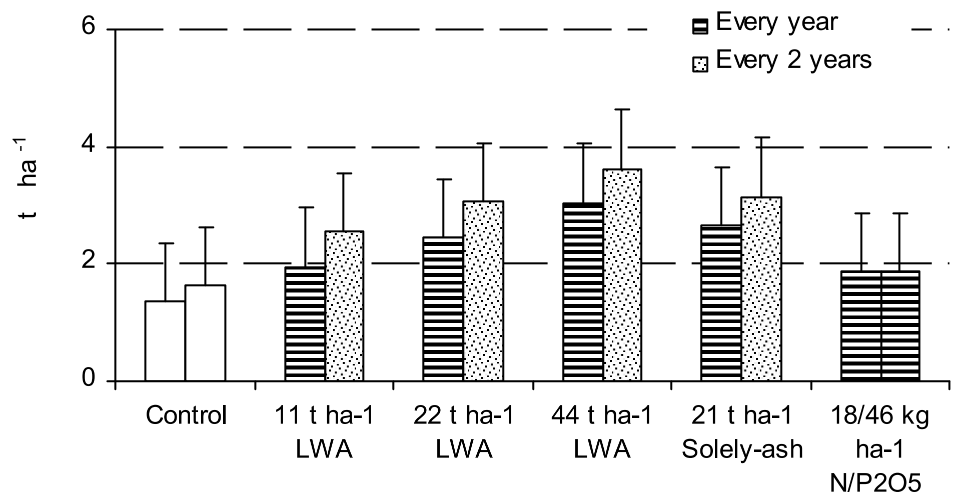

Figure 6. Faba bean seed yield obtained from the use of litter-wood ash (with 2 application periods) and chemical fertilizer (with every year application). LWA (Litter-wood ash)

The effect of ash application on soil properties

A number of litter-wood ash samples preserved for years were collected from different farmers' houses for physical and chemical analysis (Tables 6 and 7). The laboratory results for the representative litter-wood ash samples showed they had a strong alkaline pH condition (8.92) with EC values 1.71 dS m^{-1}. It was rich with phosphorus and potassium contents and had optimal C:N ratio. The litter and unbleached materials contained 1.86% organic carbon (Table 6**).** Application of litter-wood ash had the capacity to neutralize the low pH values measured for the two locations (pH 6.3 and 6.4 respectively, for Atakilt and Mush) in the top 30 cm of soil depth. Considering the correlation between pH and availability of plant nutrients as a whole, Brady (1984) indicated a pH range of 6 to 7 seems to promote the most readily available plant nutrients. The application of litter-wood ash to the soil showed a tendency to increase plant nutrients to the soil. However, table 7 indicates the total N and organic carbon content before sowing and after harvesting approximately equal for all treatments. As the ash sample had large amount of P, the available P in the soil increases as the rate of application increases. All the treatments showed low amounts of available K left in the soil after the barley crop treated with litter-wood ash. This suggests that much of the available K from the litter-wood ash might be utilized by the plant and/or the litter-wood ash made easy the uptake of the inherent soil K to the plant.

Table 6. Laboratory analysis of litter ash preserved for 3 years under farmers' condition

Characteristics	Contents
pH H_2O (1:2.5)	8.92
EC (dS m^{-1})	1.71
TN (%)	0.182
O.C (%)	1.855
C/N	10
Av.P (ppm)	245.40
Potassium (meq $100g^{-1}$ soil)	59.2

Table 7. Results of soil sample analysis before planting and after harvesting

Treatments	TN (%)	Av. P, (ppm)	Avail. K (meq/ 100 g)	OC (%)	pH, $_{H2O}$ 1:2.5	EC (mmhos/ cm)	Texture, **%**		
							Sand	Silt	Clay
Composite soil sample before the treatments	0.24	5.26	3.20	1.95	5.78	0.06	11.7	31.0	57.3
Control	0.22	4.17	1.83	1.83	5.87	0.04	10.7	30.0	59.3
4.7 ton/ha pure-ash	0.22	7.07	1.61	1.91	5.94	0.05	8.7	32.0	59.3
9.4 ton/ha pure-ash	0.22	9.70	1.37	1.37	5.96	0.05	12.7	31.0	56.3
14 ton/ha pure-ash	0.23	12.53	1.59	1.96	6.07	0.06	11.7	31.0	57.3
21 ton/ha pure-ash	0.22	47.67	2.08	1.92	6.58	0.12	10.7	34.0	55.3
41/46 N/P2O5 kg/ha	0.22	4.38	1.33	1.90	5.81	0.03	15.7	27.0	57.3

Conclusions and Recommendations

The use of litter-wood ash as a nutrient source for food crop production depends largely on the prevailing farming system and farmers' fuel tradition. Since most farmers in the study areas do have very similar fuel wood sources based on our results from this study we like to make the under mentioned, suggest and recommendations in terms of litter-wood ash application. In North Shewa area and other similar areas, litter-wood ash could be used as the best soil amendment material that adds plant nutrients to the soil. The use of litter-wood ash as a nutrient source for food crop production depends largely on the prevailing farming system and farmers tradition. Applications of litter-wood ash based on agronomic principles such as lime requirement or fertility recommendations have the potential to increase yields in dry matter, and grain. Single applications of litter-wood ash resulted in long-term increases in plant productivity. Farmers in acid soil, waterlogging areas could be advised and encouraged to use litter-ash under their crops. If managed properly, litter-wood ash could be sustainable alternative to agricultural lime, with many economic and environmental benefits. In order to get yield advantage, farmers from litter-wood ash application, farmers should apply minimum of 11 t ha^{-1} and 11 - 22 t ha^{-1} of litter-ash for faba bean and barley, respectively. Hence, farmers should be advised to store their litter-wood ash mixtures away from runoff and avoid its application immediately after prolonged rainfall. If additional fertilizer applications are needed, there should be formulated. Since ash has low density and small particle size, it is necessary to avoid spreading it on very dry days. Also it is necessary to avoid the use of pesticide chemicals at least for 3 to 5 days prior to ash application since ash has absorbent nature to the chemicals.

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