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Research Article

Management of Alternative Organic Fertilizer Sources for Wheat Production: Evidence from Decomposition Dynamics and Agronomic, Economic, and Farmers' Preferences

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The increasing cost of mineral fertilizer has posed a barrier for smallholder farmers, resulting in lower application rates, declined soil fertility status, and crop yield. Therefore, it is vital to look for cheap, impactful, and locally accessible organic fertilizer sources. Thus, two-year on-farm studies were conducted to evaluate potential organic fertilizer sources based on their decomposition dynamics and agronomic, economic, and farmer preference responses. The organic fertilizer sources used were dried tree leaves of *Croton macrostachyus* (Cm) and *Erythrina bruci* (Eb) and farm yard manure (FYM) and their mixture at ratios of 1 : 1:0, 2 : 1:0, and 1 : 1:1 Cm : Eb : FYM, respectively. The organic materials were buried using litter bags at 5 tons ha^{-1} rate in the crop field and retrieved at the weeks of two (14 days), four (28 days), six (42 days), and eight (56 days) after placement. Data were collected that included dry mass (DM) remaining, daily decomposition rate (k), and half-life ($t1/2$). Furthermore, to validate the findings of litter bag trials, the mixture of three organic fertilizer sources [1 : 1 : 0, 2 : 1 : 0, and 1 : 1 : 1 of Cm : Eb : FYM] and four application times (two, four, six, and eight weeks before sowing) were evaluated on bread wheat (*Triticum aestivum*) as a test crop in factorial randomized complete block design in a factorial arrangement with three replications. Data on agronomic, economic, and farmers' preferences were recorded. The result revealed an increased weight loss over 56 days in the order of 2 : 1 : 0 > 1 : 1 : 0 > 1 : 1 : 1. The k value significantly ($P < 0.05$) varied among organic fertilizer sources. The k value (% day^{-1}) in 2013 varied between 3.42% and 0.023%, whereas in 2014, it was 3.10% and 0.23% for Cm and FYM, respectively. The k value was in the order of Cm > 2 : 1 : 0 > 1 : 1 : 0 > Eb > 1 : 1 : 1 > FYM. Applying organic fertilizers two weeks before sowing significantly improved wheat performance compared to applications made eight weeks prior. For example, the mean grain yield was 4.1 tons ha^{-1} and 2.6 tons·ha^{-1} at two and eight weeks before sowing, respectively. Although there were no statistically significant differences among the mixed sources, the 2 : 1 and 1 : 1 over 1 : 1 : 1 proportion have resulted in a higher grain yield. Farmers showed the highest preference rank for 2 Cm : 1 Eb and 1 Cm : 1 Eb, incorporated two weeks before sowing. The partial budget analysis demonstrated the highest net benefit from applying two weeks before sowing and 2 Cm : 1 Eb organic material mixture. Considering the findings generated from the decomposition test, agronomic and economic evaluations, and farmers' preferences, we could conclude that the wheat growers should use 2 Cm : 1 Eb and incorporate it into the soil two weeks before sowing.

1. Introduction

Researchers and decision-makers are becoming more interested in maintaining soil health to fulfill the rising need for agricultural production to meet the world's needs for food and energy [1]. An increase in productivity is likely attained through an adequate and balanced supply of nutrients. An increase in productivity is likely attained through an adequate and balanced supply of nutrients. To meet the nutrient needs of crops, employing organic resources would therefore be a necessary practice [1–8].

According to various studies [1, 7, 9], organic materials are considered a source and a repository of many essential plant nutrients that can be rendered available to succeeding crops through litter decomposition. Additionally, they compensate for minor deficits in secondary and micronutrients not addressed by mineral fertilizers. Additionally, by concurrently enhancing several ecosystem processes, using organic sources can lessen the requirement for the excessive input of synthetic fertilizers [1, 10].

Fundamental processes that support ecosystem function include the mineralization and decomposition of organic matter. The size and makeup of the microbial population, the quantity and quality of litter (i.e., its physical and chemical qualities), and climate and soil conditions are only a few of the variables that affect how quickly organic matter decomposes. For example, the carbon-nitrogen ratio (C/N ratio) is a parameter that relates to the breakdown of organic matter and indicates the amount of nitrogen present in the soil. The speed of decomposition is influenced by the C/N ratio [4]. Since the microflora (bacteria, fungi, and actinomycetes) satisfy the N requirements and are not a limiting factor, microorganisms have more substantial mineralization when the organic matter has a high N content. On the other hand, if the N concentration is low, the rate of organic matter decomposition declines. Adding nitrogenous sources affected the carbon mineralization rate in such circumstances [11].

According to several scholars, management strategies impact how well organic fertilizer sources function on the soil and crop productivity. In light of this, Sangakkara et al. [12] indicated improved soil characteristics and maize growth when *Gliricidia* leaves were incorporated two weeks before planting, and *Tithonia* leaves and rice straw were incorporated four weeks before planting. The authors observed suppressed growth of maize when organic materials were applied at planting. On the other hand, Omisore et al. [13] obtained the highest cob weight and grain yield of maize by applying poultry manure two months before planting. Moreover, the different application times of organic materials such as manure three weeks before tef (*Eragrostis tef* (Zucc.) Trott) sowing [14], compost two weeks after maize (*Zea mays* L.) sowing [15] and at sowing [16], and leaves of *Erythrina bruci* one month before sowing wheat [17] were reported in their research activities.

Farmers in the Wolaita area of Southern Ethiopia have a tradition of laying tree branches to shed their leaves on cropping fields as an organic fertilizer source, such as those from *Erythrina bruci, Croton macrostachyus, Cordia africana*, and others [18]. Notwithstanding the crucial functions of organic inputs, the resources are not managed effectively [19]. The management problems with utilizing locally available organic materials are associated with applying potential nutrient sources in the amount needed at the right time and place to meet the crop demand. These may result in low asynchrony between nutrient release and demand by the crop [20].

Meanwhile, farmers have been applying organic materials based on their availabilities and experiences. For instance, personal communication with farmers in the Wolaita area showed that manure is applied in the range varying between two and sixteen weeks prior to sowing/planting. The timing and amount of application for other organic fertilizer sources such as leaves and home leftover residues have been arbitrary. These may affect the synchrony of the nutrient release with crop demands. Thus, the preceding evidence-based information calls for the need to devise standards for the optimal and sustainable management of organic fertilizer sources. The study aimed to understand the decomposition dynamics of mixed organic materials, assess their optimal application rates, and evaluate their impact on crop performance which was needed. Hence, this farmer-participatory on-farm research was conducted with the objectives to evaluate the decomposition pattern of organic fertilizer sources, evaluate organic fertilizer sources' agronomic and economic effects on wheat productivity under farmers' field conditions, and evaluate farmers' preferences for the crop stands in response to locally available organic materials and also increase the farmers' involvement in using organic fertilizer sources. In this study, we hypothesized that applying locally available materials, such as *Croton macrostachyus* and *Erythrina bruci* leaves, along with farm yard manure prior to sowing could furnish nutrients when the plant requires and enhance agronomic and economic performance of wheat by improving soil fertility.

1.1. Description of the Study Area. The study was conducted for two years on a farmer's field in Kokate Mara Chare *Kebele*, Sodo Zuria District (*Woreda*), Wolaita Zone, Southern Ethiopia Region. In the site, there was an established Farmers' Research Group (FRG) consisting of 10 farmers (8 males and 2 females) in which the experiments were conducted in one of the selected farmers' fields. The location of the site is 6.88270° latitude and 37.79292° longitude, with the minimum and maximum average annual temperatures of 14.3 and 25.6°C, respectively and an average annual rainfall of 1200 mm (National Meteorology Agency, Wolaita Sodo branch). The altitude of the site is 2243 m.a.s.l. The agroecology of the Wolaita area is 70% *Kolla* (lowland) (500–1500 m.a.s.l) and 30% *Woina Dega* (midhighland) (1500–2000 m.a.s.l) with two major cropping seasons *Belg* (minor rainy season) and *Meher* (primary rainy season) [21]. The area has soil types called Eutric Nitisols and Humic Nitisols. These soils are very deep, reaching a depth of up to 10 meters. They are dark reddish-brown [22].

1.2. Experimental Setup. The study consisted of two sets of experiments under field conditions. One group was a study on the decomposition of organic fertilizer sources using a litter bag, and the other group was farmers' participatory evaluation of organic materials' effects on bread wheat *(Triticum aestivum)* variety "*Digalo*" productivity.

Both *Croton* (*Croton macrostachyus*) and *Erythrina* (*Erythrina bruci*) trees are common in the study area as live fences of homes, farm boundaries, and within crop fields and surroundings. In the belief that the trees would improve the soil's condition, farmers prune and lay tree branches on crop fields until the leaves are shed and plowed with soil. In addition, the farm yard manure is applied based on availability to maintain soil fertility. Report in [17] indicated that *Erythrina bruci* is a fast-growing N-fixing leguminous tree endemic to Ethiopia which could increase soil fertility.

Reports in [2, 17] also indicated that both *Croton* (*Croton macrostachyus*) and *Erythrina* (*Erythrina bruci*) trees decompose fast and release nutrients to improve the fertility of soils and hence improve productivities of crops. In light of these facts, the leaves of *Croton macrostachyus* (Cm) and *Erythrina bruci* (Eb) that were picked in the green stage and farm yard manure (FYM) were selected as sources of organic fertilizers for investigation.

The decomposition study investigated the sole and mixed proportions of organic materials. The mixed proportions were 1 : 1 and 2 : 1 ratios for the leaves of Cm and Eb, respectively, and 1 : 1 : 1 for Cm, Eb, and FYM, respectively. The fresh leaves were shredded to reduce the pieces to less than 10 cm in size, dried under shade for 7 to 14 days, and then oven-dried at 70°C until a constant weight was recorded. In addition, the well-dried FYM under the shed and oven dry at 70°C was used for the experiment. Then, a portion of each sample was taken to the laboratory for analysis, while another portion was directly used for field study.

1.2.1. Chemical Composition of Organic Fertilizer Sources. The leaves of *Croton macrostachyus* (Cm) and *Erythrina bruci* (Eb) collected from the tree leaves were chopped, dried in the shade, and then oven-dried at 70°C until they achieved constant weight. After preparation, the organic materials, including farm yard manure (FYM), were used to analyze nitrogen (N), phosphorous (P), potassium (K), organic carbon (OC), and C : N contents according to the procedure outlined by Sahlemedhin and Taye [23]. The samples were analyzed at the JIJE Analytical Testing Service Laboratory, Addis Ababa, Ethiopia. The organic carbon (OC) content of the soils was determined following the wet combustion method of Walkley and Black. The phosphorous (P) and potassium (K) contents were determined using the dry ashing method, and total nitrogen was determined by the micro-Kjeldahl digestion method. The initial chemical characteristics of organic fertilizer sources are shown in Table 1. The result implies that the leaves have high nutrient content with less C : N ratio.

1.2.2. Field Decomposition Experiment Using Litter Bag. The decomposition experiment under the field was monitored using the litter bag method [24]. A litter bag with $0.2\ \mathrm{m} \times 0.2\ \mathrm{m}$ ($0.4\ \mathrm{m}^2$) size was prepared from nylon sheets. A total of six different organic fertilizer sources, such as three sole contents (Cm, Eb, and FYM) and three mixtures at a ratio of 1 : 1 : 0, 2 : 1 : 0, and 1 : 1 : 1 of Cm : Eb : FYM, respectively, each at a rate of 5 t/ha in three replications were inserted into the litter bag. A total of 72 litter bags (six types of organic fertilizer sources × four litter bags/treatment × three replications) were prepared to monitor the decomposition of organic material sources. These litter bags were tied with labeled tags and buried into the soil at a depth of plow layer (i.e., 20 cm) adjacent to the field where the crop response study was conducted. The decomposition experiment was conducted under field conditions using randomized complete block design (RCBD) in a factorial arrangement with three replications. At each sampling, 18 litter bags (6 treatments × 3 replications) were carefully retrieved at 14, 28, 42, and 56 days after application. From the litter bags, materials that were attached, such as soil, worms, and plant roots, were removed carefully, placed into a sample bag made of paper, and transported to the laboratory for analysis. Then, the residues were removed from the bags and rinsed with distilled water. The dry mass (DM) remaining in each bag was then measured and presented as a percentage remaining in each period in comparison to their initial amounts using the following equation:

$$\mathrm{DM}\,(\%) = \frac{W_t}{W_O}\, x\ 100, \quad (1)$$

where W_t = weight remained after each sampling time (g) and W_O = initial weight (g), potentially decomposable. The data for DM from each treatment were fitted to a negative exponential model extensively used to describe litter decomposition in litter bags [25].

$$W_t = W_O e^{(-\mathrm{kt})}, \quad (2)$$

where W_t = litter remaining after a given time (t) in days, W_O = initial residue weight at time zero, t = time interval of sampling expressed in weeks, k = constant of decomposition per day, and e = base of natural logarithms ($e = 2.718$). The exponential model was transformed into a natural logarithm to determine the values of k as follows:

$$\ln\left(\frac{X_t}{X_O}\right) = -\mathrm{kt}. \quad (3)$$

The regression of ln $(X_t/X_O) = -\mathrm{kt}$ overtime was also performed separately to provide independent estimates of k and R^2 for each treatment. Moreover, half-life ($t1/2$) was calculated from the k value as $t1/2 = -\ln\,(0.5)/k = (0.693/k)$ [26], which expresses the time required for half of the residues to be decomposed or for half of the nutrients contained in the residues to be released.

1.2.3. Crop Response Experiment

(1) Treatments and Experimental Design. The land was cleared and plowed using an oxen plow. After leveling, the layout was prepared against the slope. The mixture of organic fertilizer sources and their application time were considered as factors studied in the experiment. The treatments for the mixture of organic fertilizer sources were 1 : 1 : 0, 2 : 1 : 0, and 1 : 1 : 1 of Cm : Eb : FYM, respectively. The treatments regarding the application time were two, four, six, and eight weeks before sowing. The organic fertilizer sources were applied at a rate of 5 tons·ha^{-1} based on the results reported by Ermias and Fanuel [2], and Fanuel and Gifole [16]. The materials were manually incorporated into the soil at a depth of 20 cm in the experimental field. The experiment was conducted for two years in one farmer's field using RCBD in a factorial arrangement with three replications. The plot size was 2 m by 2 m ($4\ \mathrm{m}^2$). All treatments received a full dose of blanket-recommended diammonium phosphate (DAP) [18-46-0)

Table 1: The chemical composition of dried green leaves of *Croton macrostachyus* (Cm), *Erythrina bruci* (Eb), and farm yard manure (FYM).

Organic fertilizer sources	OC (%)	N (%)	P (mg/kg)	K (mg/kg)	C: N —
Cm	50.83	5.20	11.07	30,651.23	10.00
Eb	51.83	4.70	18.59	21,239.24	11.00
FYM	52.00	1.55	1083.00	6,606.60	33.50

Cm = *Croton macrostachyus,* Eb = *Erythrina bruci,* and FYM = farm yard manure.

and 40% of blanket-recommended urea fertilizer. The recommended dose of urea and DAP for wheat was 100 kg urea ha^{-1} (46 kg N) and 150 kg DAP ha^{-1} (27 kg N and 30 kg P). DAP was applied at sowing time. Urea was applied, half at sowing and the remaining one month after planting. A bread wheat variety, "Digalo," at the 125 kg/ha seeding rate, was sown using drilling at 25 cm spacing. Except for the treatment differences, crop management practices for all trial plots were similar.

(2) Data Collection. Four central rows from the plot were harvested for data collection. Parameters, such as growth, yield components, and grain yield, were recorded. The growth data included plant height, spike length, straw, and biomass weights. The yield component data recorded includes the number of seeds/spikes, the number of tillers (fertile and infertile) per plant, and 1000 seed weights. Grain yield was collected on a plot base, and after a 12.5% moisture adjustment, it was converted to tons ha^{-1}

1.3. Farmers' Crop Stand Preferences. Data on farmer preferences were gathered when the crop approached physiological maturity. Farmers were divided into four groups, with one replication given to each group. Farmers were asked to use their knowledge of plant stand, tillering, spike length, observed seed set on a spike, and expected straw and grain yield to assess the crop stand. Each group had a secretary who kept track of each participant's preferences. The group members assessed each treatment on the block until they agreed on the standards provided by the group (noted above) for assigning ranks. In this course, there was an intensive discussion about whether each treatment performed well or not about evaluation points. Finally, the group reached a consensus and developed shared ranking preferences to be presented to other groups. To summarize farmers' rank, the tally method used the first, second, and third rankings with weighted point values of three, two, and one, respectively.

1.4. Economic Performance. The partial budget analysis was carried out using the methodology described by CIMMYT [27]. The following steps were used for partial budget analysis:

(a) Total income (birr) = income from grain yield + straw.

(b) Total variable costs (birr) include labor costs for organic material collection, preparation, and application. The difference is application time.

(c) Net benefit (birr) = gross return – total variable cost.

The partial budget analysis used the mean grain yield data of selected treatments. The average field price of 1 ton of wheat grain that farmers receive for the sale of the crop during the experimental period (2013 and 2014) was 5000 Ethiopian birr (ETB) based on the market price of wheat grain at Sodo town near the study site, 390 km away from Addis Ababa. The amount of organic materials used for this experiment was 5 tons/ha. The average labor cost for preparing organic materials was 100 birr/tons, and 60 ETB/tons was for incorporating organic material. The gross benefit was calculated as the average adjusted grain yield (kg ha^{-1}) × field price farmers receive for the crop sale (5000 ETB/tons). The average grain yield was adjusted to 10% downwards to reflect the difference between the experimental yield and the yield of farmers expected from the same treatment. Total variable cost was calculated as the sum of all costs that are variable or specific to a treatment against the control. Net benefit was calculated by subtracting the total variable cost from the gross benefit.

1.5. Data Analysis. Data obtained from the two sets of experiments were subjected to analysis of variance using a general linear model of the statistical analysis system (SAS) [28] software version 9.1. Factorial RCBD assumptions were followed in the data analysis because the studies were carried out in a field setting. Effects were considered significant if P values were less than 0.05. Significant differences among treatment means were tested using the least significant difference (LSD) test at a 5% significance level. Economic analysis calculations were performed using Microsoft Excel.

2. Results

2.1. Decomposition Pattern of Organic Materials. Organic fertilizer sources alone and in a mixture showed variation in dry weight loss (Figures 1(a) and 1(b)). The sole of Cm leaves and its mixtures at a 2 : 1 ratio (Cm : Eb, respectively) during 2013 and 2014 recorded more rapid mass loss followed by a 1 : 1 mixture. The evaluation of weight loss among organic fertilizer sources revealed significant differences ($P < 0.001$) (Figures 2(a) and 2(b)). Rapid weight loss was recorded in the order of 2 : 1 > 1 : 1 > 1 : 1 : 1, in which the organic material mixture consisting of more leaves of Cm revealed higher weight loss. During the eight weeks of decomposition period, the application of FYM (alone followed by its mixture with Cm: Eb leaves) showed the least weight loss, which suggests more than eight weeks to break down and release nutrients to the crop. This might be due to higher C/N ratio (Table 1).

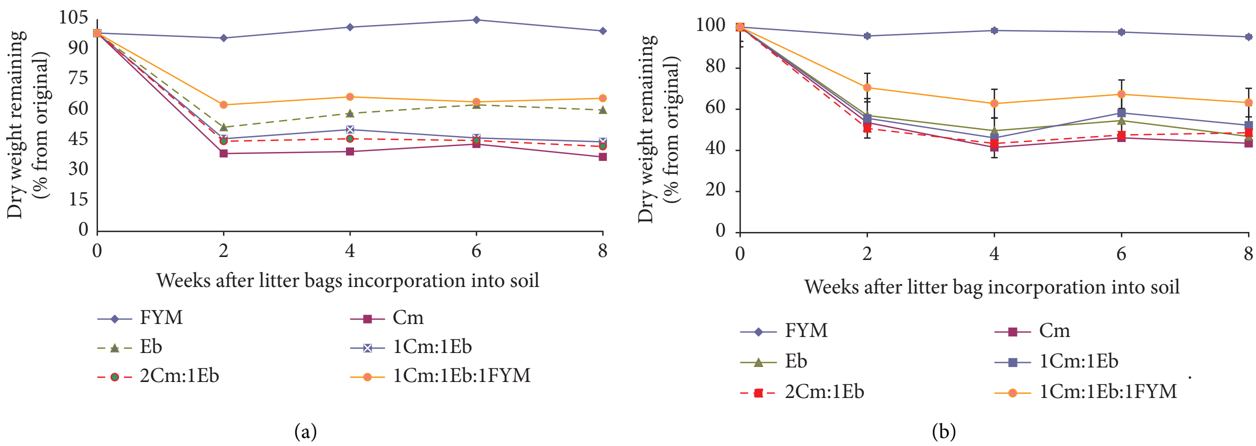


FIGURE 1: (a) Dry weight (%) remaining in the litter bags at different weeks after incorporation into the soil at Kokate Mara Chare, Wolaita, in the 2013 cropping season. (b) Dry weight (%) remaining in the litter bags at different weeks after incorporation into the soil at Kokate Mara Chare, Wolaita, in the 2014 cropping season.

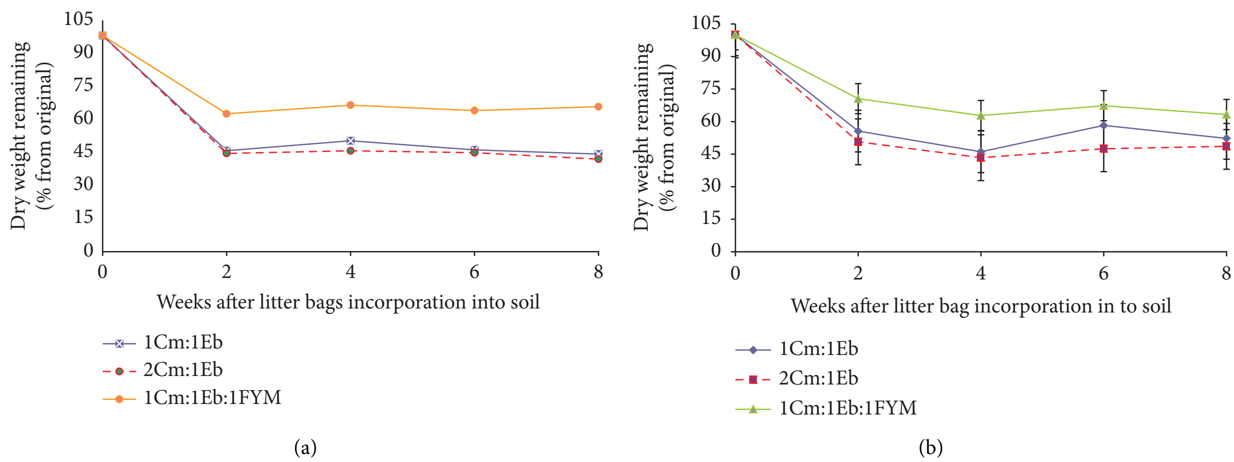
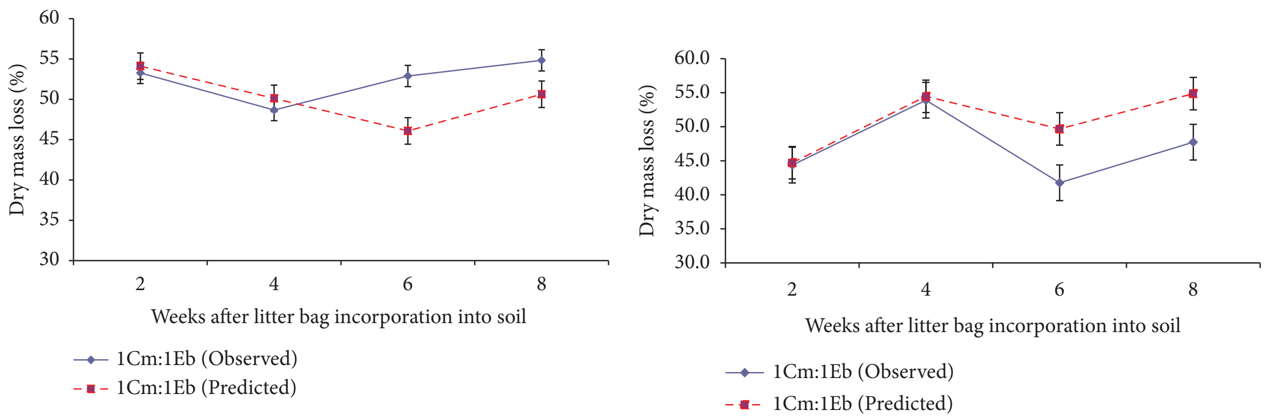


FIGURE 2: (a) Dry weight (%) of remaining litter mixtures in the litter bags at different weeks after incorporation into the soil at Kokate Mara Chare, Wolaita, in the 2013 cropping season. (b) Dry weight (%) of remaining litter mixtures in the litter bags at different weeks after incorporation into the soil at Kokate Mara Chare, Wolaita, in the 2014 cropping season.

The daily decomposition rate (k value) significantly ($P < 0.05$) varied among organic fertilizer sources. The k values (% day^{-1}) in 2013, averaged over 56 days of incubation, were Cm (3.42%) > 2 : 1 (2.94%) > 1 : 1 (2.76%) > Eb (2.11%) > 1 : 1:1 (1.59%) > FYM (0.023%). In 2014, the k values (% day^{-1}), averaged over 56 days of incubation, were in the order of Cm (3.10%) > 2 : 1 (2.97%)>1 : 1 (2.50%) > Eb (2.45%) > 1 : 1:1 (1.75%) > FYM (0.23%). In all cases, FYM was resistant to decomposing and needed additional time before applying to the crop field.

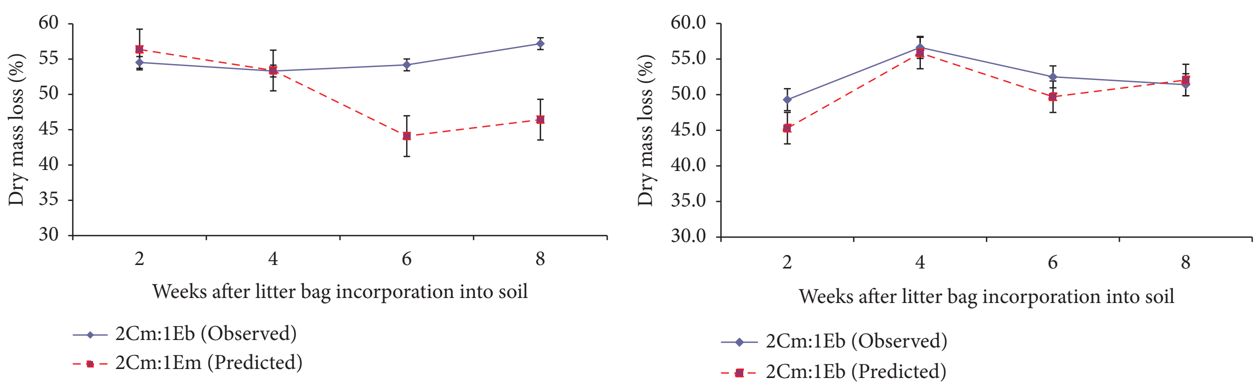
2.1.1. Interaction of Mixed Organic Materials. The existence of interactions in the mixed organic fertilizer sources was analyzed by plotting the observed and predicted mass loss/ nutrient content. A 1 : 1 line indicated no fundamental interactions (additive effect), while any deviation from this line indicates nonadditive interaction, which is positive (synergistic) or adverse (antagonistic) in its nature. Figures 3(a), 3(b)–5(a), and 5(b) indicate nonadditive interactions in the litter mixture. In 2013, observed mass loss was less than that predicted between the second and fourth weeks for 1 : 1 and 2 : 1 Cm and Eb, respectively, indicating an antagonistic interaction. Then, it shifted to synergistic interaction (observed mass > predicted mass) at the end of the fourth week. The result implied that the 1 : 1 and 2 : 1 proportions of Cm and Eb shifted to synergistic interaction and enhanced the mass loss in the litter mixture (Figures 3(a) and 4(a)).

The mixture of 1 : 1 : 1 Cm : Eb : FYM, respectively, during 2013 showed a 1 : 1 line (an overlapped interaction) indicating nonreal interactions (additive effect) up to 4 weeks and after fourth weeks (observed mass loss > - predicted mass loss) and shifted to synergistic interaction (enhanced the mass loss in the mixture) (Figure 5(a)). During 2014, observed and predicted mass losses using different dry weight trials on 1 : 1 proportion highlighted higher losses on predicted mass than observed mass (Figures 3(a) and 3(b)). Data regarding the 2 : 1 mixture showed higher observed mass loss than predicted. The



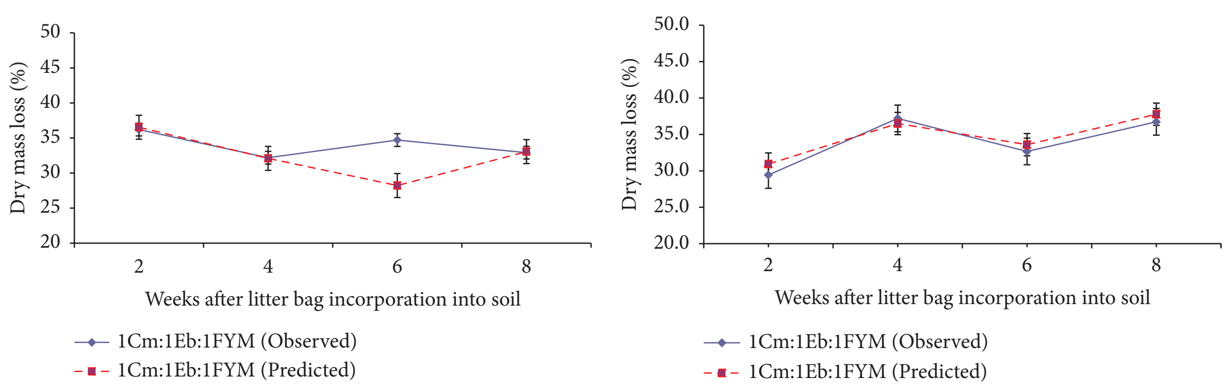
(a) (b)

Figure 3: (a, b) Relationship between predicted and observed dry mass loss (%) in 1 : 1 Cm : Eb, respectively, in Kokate Mara Chare, Wolaita, at different weeks of 2013 and 2014, respectively.



(a) (b)

Figure 4: (a, b) Relationship between predicted and observed dry mass loss (%) in 2 : 1 Cm : Eb, respectively, in Kokate Mara Chare, Wolaita, at different weeks of 2013 and 2014, respectively.



(a) (b)

Figure 5: (a, b) Relationship between predicted and observed dry mass loss (%) in 1 : 1 : 1 Cm : Eb : FYM, respectively, in Kokate Mara Chare, Wolaita, at different weeks of 2013 and 2014, respectively.

result was consistent with 2013. Mixtures at equal proportions (1 : 1 : 1) during 2014 indicated that observed and predicated mass losses almost overlap (Figures 5(a) and 5(b)). In general, the data for two years presented in Figures 3(a), 3(b)–5(a), and 5(b) illustrate consistent trends in 2 : 1 mixtures of Cm : Eb, respectively, in which observed mass loss was more than predicted. This synergistic interaction, starting at the early stages of decomposition, also showed the presence of mineralization in the litter mixture. The result also indicates the ready availability of nutrients starting from the early stage of crop growth.

2.2. Agronomic Performance. Application time of organic fertilizer sources during 2013 and 2014 significantly influenced the plant height of wheat (Tables 2and 3). The most extended plant heights were recorded eight weeks before sowing, while the shortest ones were recorded two weeks before. The use of different proportions of organic materials did not affect plant height. Spike length on wheat was not influenced by the application time and proportions of organic materials (Tables 2 and 3). During 2013, the number of spikelets per spike was significantly affected by application time but not by their proportion (Table 2). Generally, the number was increasing as the application time got earlier. The number of seeds per spike was significantly affected by the application time of organic materials but not by the proportion (Table 2). The number of seeds per spike was the highest (58.42) and the lowest (50.75) at the application two and eight weeks before sowing, respectively.

The total and productive number of tillers per plant on wheat was significantly affected by the application time of organic materials but not by the proportion (Table 2). The maximum total (2.17) and productive tillers per plant (1.96) were recorded by applying organic materials two weeks before sowing. The least in both cases were recorded from eight weeks of application prior to sowing. The maximum total and productive number of tillers per plant was statistically at par with four and six weeks' application of organic materials before sowing. Data from 2014 indicated that neither the application time nor the proportion of organic materials affected spikelet spike^{-1}, seeds spike^{-1}, tiller plant^{-1}, and productive tillers plant^{-1} (Table 3).

Application time and proportion of organic materials significantly affected wheat biomass yield in the 2013 growing season (Table 2). The biomass yield was increased as organic materials were applied two weeks before sowing. The mean value was 10.8 tons ha^{-1} and 7.4 tons ha^{-1} for two and eight weeks before sowing, respectively. The mean value was 10.8 tons ha^{-1} and 7.4 tons ha^{-1} for two and eight weeks before sowing, respectively. In addition, the maximum (9.42 tons ha^{-1}) and the minimum (8.09 tons ha^{-1}) biomass yield of wheat was under 2 : 1 and 1 : 1:1 proportions, respectively.

Meanwhile, the 2 : 1 proportion was statistically at par with the 1 : 1 proportion of organic materials. During 2014, biomass yield was significantly affected only by application time. Maximum (12.4 tons ha^{-1}) and minimum (10.1 tons ha^{-1}) biomasses were attained at four and eight weeks of the application prior to sowing, respectively (Table 3). Applying organic materials two weeks before sowing was statistically at par with applying four weeks before sowing.

The grain yield of wheat during the 2013 growing season was significantly affected by the time of application and the proportion of organic materials (Table 2). Grain yield was increasing when the application time was approaching sowing time. The mean grain yield values were 4.1 tons ha^{-1} and 2.6 tons ha^{-1} under the application of organic fertilizer sources at two and eight weeks before sowing, respectively. The grain yield of organic fertilizer mixtures indicated the maximum (3.5 tons ha^{-1}) and the minimum (3 tons ha^{-1}) at 1 : 1 and 1 : 1 : 1 proportions, respectively. However, the 1 : 1 proportion was statistically at par with the 2 : 1 proportion of organic materials. The grain yield during 2014 revealed a significant difference due to application time but not the proportion of organic materials (Table 3). The trend was similar in 2013. The highest (3.64 tons ha^{-1}) and the least (2.73 tons ha^{-1}) mean grain yields were from two and eight weeks of the application prior to sowing, respectively. However, applications of four and six weeks prior to sowing were statistically at par with two-week applications. The better mineralization of 2 : 1 mixtures of Cm and Eb over 1 : 1 and 1 : 1 : 1 mixtures might have resulted in superior biomass and wheat grain yield performance without significant differences. The thousand-grain weight of wheat during 2013 and 2014 was not significantly affected by the application and proportion of organic materials (Tables 2 and 3).

2.3. Farmers' Crop Stand Preference Evaluation. The farmers' crop preference ranks for 2013 and 2014 are indicated in Tables 4 and 5. The farmers' preference result during the 2013 growing season indicated that T12 = 2 weeks with 1 : 1 (Cm : Eb) and T13 = 2 weeks with 2 : 1 (Cm : Eb) were their top preferences, followed by $T = 14$ with 1 : 1 : 1 (Cm : Eb : FYM) and T10 = 4 weeks with 2 : 1 (Cm : Eb), respectively (Table 4). Farmers during the 2014 growing season provided the first, second, and third ranks to 2 weeks of application for 1 : 1 (Cm : Eb), two weeks for 2 : 1 (Cm : Eb), and four weeks for 1 : 1 (Cm : Eb), respectively (Table 5). From the two-year results, it was noted that the application of organic fertilizer sources at 1 : 1 and 2 : 1 Cm : Eb proportion and two weeks before sowing, respectively, had taken the attention of farmers due to their visible differences in the field condition.

2.4. Partial Budget Analysis. Partial budget analysis during 2013 revealed the highest gross income (18450 birr) for two weeks' application before sowing. It was followed by four weeks and a 2 : 1 proportion. The least gross income (11700 birr) was observed for eight weeks of application prior to sowing (Table 6). Partial budget analysis was also consistent during 2014, in which the highest income was attained from two weeks of application followed by four weeks and a 2 : 1 proportion. The least was obtained from the application of eight weeks with the mixture of 1 : 1 : 1 (Cm : Eb: FYM) (Table 7).

3. Discussion

Both leaf litters (Cm and Eb) had an initial C : N ratio of less than 20 : 1 and N contents above 2.5%, considered the % N baseline threshold for high-quality organic matter that will result in short-term N mineralization in soil [19]. This result

Table 2: Growth, yield components, and grain yield data of wheat as influenced by time and proportion of organic materials application at Kokate Mara Chare, Wolaita, in 2013 cropping season.

Treatments	Plant height (Cm)	Spike length (Cm)	Spikelet spike^{-1} (No.)	Seeds spike^{-1} (No.)	Tiller plant^{-1} (No.)	Productive tillers plant^{-1} (No.)	Biomass (tons ha^{-1})	Grain yield (tons ha^{-1})	Thousand seed weight (gm)
Application time (weeks before sowing)									
Two	97.03a	5.34	17.52a	58.42a	2.17a	1.96a	10.8a	4.1a	41.55
Four	93.72b	5.15	17.14ab	55.70a	1.93ab	1.80ab	9.6b	3.6b	42.93
Six	90.21c	5.37	16.54bc	54.40ab	1.83ab	1.75ab	8.0c	2.9c	40.62
Eight	88.58c	4.99	16.12c	50.75b	1.61b	1.49b	7.4c	2.6c	40.08
$LSD_{0.05}$	2.58	ns	0.96	4.90	0.38	0.33	1.1	0.4	ns
Proportion									
1 : 1	92.65	5.25	16.49	55.20	1.82	1.74	9.42a	3.4a	41.15
2 : 1	92.99	5.16	16.81	53.78	1.85	1.71	9.36a	3.5a	42.37
1 : 1 : 1	91.51	5.37	17.20	55.47	1.99	1.81	8.09b	3.0b	40.36
$LSD_{0.05}$	ns	ns	ns	ns	ns	ns	0.9	0.3	ns
CV (%)	3.36	10.32	6.86	10.77	24.5	22.8	14.34	14.52	8.74

ns = nonsignificant; means with the same letter show no significant difference, 1 : 1(Cm : Eb), 2 : 1 (Cm : Eb), and 1 : 1 : 1 (Cm : Eb : FYM).

Table 3: Growth, yield components, and grain yield data of wheat as influenced by time and proportion of organic materials application at Kokate Mara Chare, Wolaita, in 2014 cropping seasons.

Treatments	Plant height (Cm)	Spike length (Cm)	Spikelet spike^{-1} (No.)	Seeds spike^{-1} (No.)	Tiller plant^{-1} (No.)	Productive tillers plant^{-1} (No.)	Biomass (tons ha^{-1})	Grain yield (tons ha^{-1})	Thousand seed weight (gm)
Application time (weeks before sowing)									
Two	108.2a	5.5	18.9	56.6	2.1	1.4	11.9ab	3.64a	39.1
Four	106.2ab	5.9	20.3	60.3	2.4	1.7	12.4a	3.62a	38.8
Six	103.7ab	5.9	20.2	59.4	2.4	1.6	10.4b	3.30a	38.2
Eight	101.2b	5.6	19.6	58.6	2.3	1.6	10.1b	2.73b	36.6
$LSD_{0.05}$	5.07	ns	ns	ns	ns	ns	1.9*	0.48**	ns
Proportion									
1 : 1	104.8	5.7	19.8	58.2	2.3	1.5	10.9	3.24	39.1
2 : 1	105.1	5.6	19.8	58.2	2.2	1.6	11.9	3.52	38.8
1 : 1 : 1	104.6	5.6	19.8	59.5	2.4	1.6	10.8	3.20	37.1
$LSD_{0.05}$	ns	ns	ns	ns	ns	ns	ns	ns	ns
CV (%)	5.83	7.67	10.5	12.4	29.7	37.6	20.7	17.4	6.86

ns = nonsignificant; means with the same letter show no significant difference, * = Significant at ($P = 0.05$), ** = high Significant at ($P = 0.01$), 1 : 1(Cm : Eb), 2 : 1 (Cm : Eb), and 1 : 1 : 1 (Cm : Eb: FYM).

Table 4: Summary of farmers' preference during stand evaluation of crop, at Kokate Mara Chare, Wolaita, in 2013 cropping season.

Treatment (T)	Group 1	Group 2	Group 3	Group 4	Total point	Rank
T9	—	—	—	1 (3rd)	1	4th
T10	—	2 (2nd)	1 (3rd)	—	3	3rd
T12	3 (1st)	—	3 (1st)	2 (2nd)	8	1st
T13	2 (2nd)	1 (3rd)	2 (2nd)	3 (1st)	8	1st
T14	1 (3rd)	3 (1st)	—	—	4	2nd

*T*6 = 6 weeks (1 : 1(Cm : Eb)), *T*9 = 4 weeks (1 : 1 (Cm : Eb)), T10 = 4 weeks (2 : 1 (Cm : Eb)), T12 = 2 weeks (1 : 1 (Cm) : Eb)), T13 = 2 weeks (2 : 1 (Cm : Eb)), and *T* = 14 (1 : 1:1(Cm : Eb: FYM)), respectively. The numbers out and inside the brackets indicate the tally weight and farmers' preference rank, respectively.

is in line with the finding by Rezig et al. [9] who reported that when the organic matter has high N content (a lower C : N ratio), microorganisms have greater mineralization of N from organic matter since the microorganisms satisfy the N requirements. Phosphorus (P) content (mg/kg) was 11.07 in Cm, 18.59 in Eb, and 1083.00 in FYM. The potassium (K) content also varied from 6,606.60 mg/kg (FYM) to 30,651.23 mg/kg (Cm). Furthermore, the C : N ratio also varied between 10.00 in Cm and 33.50 in FYM, which denotes a higher decomposition of Cm and Eb than FYM, probably due to the existence of less resistant structures and organic compounds in Cm and Eb. Comparatively, the lower C : N ratio of Cm and Eb than FYM could have resulted in a faster decomposition rate of both Cm and Eb and the release of essential nutrients to the crop from these sources. Reports have also shown a higher Cm nutrient content over the leaves of Eb and FYM [17, 19, 29, 30]. However, in general, the chemical characteristics of organic nutrient

Table 5: Summary of farmers' preference during stand evaluation of crop, at Kokate Mara Chare, Wolaita, in 2014 cropping season.

Treatment (T)	Group 1	Group 2	Group 3	Group 4	Total point	Rank
T6	1 (3rd)	—	2 (2nd)	—	3	4th
T9	3 (1st)	—	1 (3rd)	—	4	3rd
T10	—	1 (3rd)	—	—	1	5th
T12	—	2 (2nd)	3 (1st)	3 (1st)	8	1st
T13	2 (2nd)	3 (1st)	—	2 (2nd)	7	2nd
T14	—	—	—	1 (3rd)	1	5th

*T*6 = 6 weeks (1 : 1(Cm : Eb)), *T*9 = 4 weeks (1 : 1 (Cm : Eb)), T10 = 4 weeks (2 : 1 (Cm : Eb)), T12 = 2 weeks (1 : 1 (Cm) : Eb)), T13 = 2 weeks (2 : 1 (Cm : Eb)), and *T* = 14 (1 : 1:1(Cm : Eb: FYM)), respectively. The numbers out and inside the brackets indicate the tally weight and farmers' preference rank, respectively.

Table 6: Partial budget analysis of application time and proportion of organic materials on wheat, at Kokate Mara Chare, Wolaita, in 2013 cropping season.

Partial budget	*Application time (weeks before sowing)*				*Proportion*		
	Two	Four	Six	Eight	1 : 1	2 : 1	1 : 1 : 1
Ave. yield (t/ha)	4.1	3.6	2.9	2.6	3.4	3.5	3.0
Adj. yield (t/ha)	3.69	3.24	2.61	2.34	3.06	3.15	2.7
Grain income (@ 5000 birr/ton)	18450	16200	13050	11700	15300	15750	13500
Total income (birr)	18450	16200	13050	11700	15300	15750	13500
Labor for organic material preparation (birr/ha)	500	500	500	500	500	500	500
Labor for organic material application (birr/ha)	300	300	300	300	300	300	300
Total variable cost (birr/ha)	800	800	800	800	800	800	800
Net benefit (birr/ha)	17650	15400	12250	10900	14500	14950	12700

1 : 1 (Cm : Eb), 2 : 1 (Cm : Eb), and 1 : 1 : 1 (Cm : Eb : FYM).

Table 7: Partial budget analysis of application time and proportion of organic materials on wheat, at Kokate Mara Chare, Wolaita, in 2014 cropping season.

Partial budget	*Application time (weeks before sowing)*				*Proportion*		
	Two	Four	Six	Eight	1 : 1	2 : 1	1 : 1 : 1
Ave. yield (t/ha)	3.64	3.62	3.3	2.73	3.24	3.52	3.2
Adj. yield (t/ha)	3.28	3.26	2.97	2.46	2.92	3.17	2.88
Grain income (@ 5000 birr/ton)	16380	16290	14850	12285	14580	15840	14400
Total income (birr)	16380	16290	14850	12285	14580	15840	14400
Labor for organic material preparation (birr/ha)	500	500	500	500	500	500	500
Labor for organic material application (birr/ha)	300	300	300	300	300	300	300
Total variable cost (birr/ha)	800	800	800	800	800	800	800
Net benefit (birr/ha)	15580	15490	14050	11485	13780	15040	13600

1 : 1 (Cm : Eb), 2 : 1 (Cm : Eb), and 1 : 1 : 1 (Cm : Eb : FYM).

sources were analyzed to show that these sources were found to be high in nutrient contents and encouraging to be used as a soil amendment based on the reports of several authors [17, 30–37]. The authors also reported that in addition to nutrient contents, organic materials could improve important soil functions by increasing soil organic matter content, enhancing microbial (fungal and bacterial) biomass and activity. Furthermore, the report in [32] indicated that application of organic fertilizer sources could improve soil physical properties by promoting soil aggregation, reducing bulk density, and increasing porosity and water percolation rate, thereby reducing runoff or soil erosion. Hence, the overall effect of using organic nutrient sources is increasing productivity of soil by improving soil's physical, chemical, and biological properties.

Overall, maximum decomposition was recorded from the tree leaves at sole and mixed application, implying that it could supply maximum nutrients to the crop within two weeks of placement. The result could be linked to a lower C : N ratio that ranged from 10 : 1 to 11 : 1. This is consistent with the results of the C : N ratio reported by Fanuel and Ermias [30] on common bean, Gindaba et al. [25] on green leaves of *Croton*, and Wassie [17] on *Erythrina* which was less than 20. However, FYM, either in sole or mixture, takes more time to decompose, which could be attributed to the higher C : N ratio (34 : 1) demonstrating the need to apply two months ahead of sowing and demands further research to suggest the appropriate time of application. The result from the present study is confirmed by Chhetri et al. [31], who reported that a high C : N ratio and low N content in chir pine retarded the decomposition process, while the low C : N and high N contents enhanced the mass loss and nutrient release in oak.

Results of the field experiment also followed the findings obtained using litter bags. It showed that time and mixes of organic fertilizer sources significantly influenced the growth and yield of wheat. Incorporation of the leaves' organic materials into the soil two weeks prior to sowing has resulted in a 44% higher grain yield of wheat compared to eight weeks. In addition, organic materials mixed at 2 : 1:0 revealed a 13% higher yield than at 1 : 1:1. This finding is in agreement with the finding reported by Sangakkara et al. [12], who indicated improved soil characteristics and growth of maize when *Gliricidia* leaves were incorporated two weeks before planting, and when *Tithonia* leaves and rice straws were incorporated four weeks before planting. Bekele et al. [34] also reported that *Croton* and *Erythrina* tree species could be incorporated into wheat cropping systems to improve crop biomass and grain yield for resource-poor farmers. The results reported in [32, 38–42] also indicated that the application of organic fertilizers like the leaves of *Croton* and *Erythrina* significantly increased the biomass and grain yields of the wheat. Furthermore, the results of researches reported by different scholars in [43, 44] for wheat and [45, 46] for maize also indicated that application of organic fertilizer sources increased yield by improving the fertility of soils. The partial budget analysis further indicated the highest income from two weeks of application and organic mixture at 2 : 1 : 0. Farmers' crop preferences during 2013 and 2014 consistently explained the superior performances of applying organic materials at two weeks at 1 : 1 and 2 : 1 ratios of Cm : Eb, respectively. The farmers' preferences agreed with the biomass and grain yield data obtained from the field trial. Overall, apart from the monitory returns of the alternative organic soil management resources, the improvements on physical-chemical-biological components of the soil in long term would provide positive impacts on soil health.

4. Conclusion

The leaves of trees located in an easily accessible radius throughout the year around the farm can be easily collected using family labor and easily stored after shed drying which are found to be the potential nutrient sources of organic fertilizer. The ease of collection, the opportunity of storing the dried leaf materials till cropping season, the opportunity of direct incorporation, and the simplicity of the preparation compared to composting have attracted the attention of participant farmers. In summary, the study conclusively demonstrated that applying a 2 : 1 ratio of *Croton macrostachyus* and *Erythrina bruci* leaves two weeks prior to sowing significantly enhanced wheat biomass and grain yield. The findings also underscored the need for further research on the optimal application timing of FYM, given its higher C : N ratio. Based on the findings, the tree leaves significantly and positively impact agronomic, economic, and farmers' preferences and could be used by wheat-growing areas of similar agroecologies. Thus, a policy and extension system that advocates and motivates smallholder farmers to integrate agroforestry practices and use them as organic fertilizer sources is suggested. It is also concluded that the finding is scalable and applicable to the context of smallholder farmers. Yet, other potential organic soil management options should be considered for large-scale production. Exploring and validating other locally available potential organic fertilizer sources are also suggested.

Data Availability

The data used to support the findings of this research are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

Authors' Contributions

The authors collected, analyzed, interpreted, and prepared the manuscript of the study.

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