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***Full Length Article***

# Appraisal of *Erythrina bruci* as a Source for Soil Nutrition on Nitisols of South Ethiopia

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## ABSTRACT

The use of locally available, nutrient rich organic sources is an effective means for improving soil fertility and increasing crop yield in view of the escalating cost of inorganic fertilizers and low fertilizer use efficiency of crops. *Erythrina bruci* is one of the endemic N-fixing leguminous trees that can be used to improve soil fertility in Ethiopia. Chemical analysis of leaf and twig samples revealed that *E. bruci* averagely has N (Nitrogen), P (Phosphorus) and K (Potassium) contents up to 4.83%, 0.38%, and 2.24%, respectively. Motivated by its high NPK content, studies were conducted for two years (2007–2008) on the effects of application of *E. bruci* biomass alone or in combination with inorganic fertilizers on the yield and yield components of bread wheat in the Kokate area of southern Ethiopia. *E. bruci* biomass (5–10 t $ha^{-1}$) incorporated into the soil one month before planting wheat have increased the grain yield of wheat by 82–127% than that of control. Biomass applied at 10 t $ha^{-1}$ produced grain and straw yields comparable to that produced with the recommended N and P fertilizers ($N_{46}P_{40}$) for wheat production in Kokate area. Combined applications of 10 t $ha^{-1}$ *E.bruci* biomass + half of the recommended dose of inorganic fertilizers ($N_{46}P_{40}$) increased grain yield by 173% over the control and gave superior yield than either input applied alone. It is concluded that resource-poor farmers can get reasonably high yields by applying biomass at 10 t $ha^{-1}$ through direct incorporation into the soil one month before planting wheat. The recommended dose of inorganic fertilizers can be reduced to half if supplemented by using 10 t $ha^{-1}$ *E. bruci* biomass. Therefore, *E. bruci* as green manure can be helpful as cost effective strategy for increased wheat yield at farm level. © 2012 Friends Science Publishers

**Key Words:** Organic nutrient sources; Inorganic fertilizers; NPK; Green manure; Yield

## INTRODUCTION

Declining status of most of the Ethiopian soils continues to decline posing a serious threat to crop production and food security. Depletion of soil fertility due to intensive cropping, shortening of the fallow period, reduced manure application, extensive use of crop residues as fuel or fodder and erosion coupled with the low inherent fertility of the soil are among the main causes of soil fertility decline (Tilahune *et al*., 2001).

Application of inorganic fertilizers mainly of urea and Diammonium phosphate (DAP) has been promoted to overcome in low soil fertility and reduced crop yields. Though crop response varies from place to place, in general substantial increases in the yields of various crops have been recorded (Amsal & Tanner, 2001; Taye *et al*., 2002). There are several cases where the yields of cereals were increased by over 100% due to fertilizer application (Kelsa *et al*., 1992).

Despite, its importance, the fertilizer use per hectare of crop land in Ethiopia is very low (14.7 kg) when compared with the world average (NationMaster.com, 2010). High pricing of fertilizers coupled with lack of financial resources of subsistent farmers limit the required use of inorganic fertilizers for optimum yield. Moreover, the inorganic fertilizer based N use efficiency is very low in Ethiopia like the rest of the world it varies with universal variable of crops or soil types and management practices (Raun & Johnson, 1999).

Therefore, application of organics as a supplement or alternative to inorganic fertilizers is important for improving soil fertility. The use of farm yard manure, compost, crop residues and mulches as organic fertilizers is an age old practice employed for improving soil fertility in Africa (Omotayo & Chukwuka, 2009). Organic nutrient sources in addition to being nutrient sources, help to build soil Organic matter (SOM), Which in turn helps soil to retain nutrients for long period of time, increase the water holding capacity of the soil, increase cation exchange capacity (CEC), improve soil structure and increase microbial activity and diversity (Dick & Gregorich, 2004). However, a number of factors those limit the use these sources as organic fertilizers also exist i.e., shortage of manure; high labor demand for compost making; bulkiness and low content in some essential plant nutrients are few to mention (Teklu *et al*., 2009). Thus, need is felt for the identification and use of nutrient rich, fast growing, organic nutrient sources with quick mineralization characteristics. A number of leguminous cover crops and trees are identified for being as high quality organic nutrient sources. Such trees include *Sesbania*, *Gliricidia*, *Leucaena etc* and cover crops such as *Crotalaria* spp., *Delicos lablab*, *Pigeon pea*, *Mucuna and Cajanus cajan* (Gachene *et al*., 1999; Cobo *et al*., 2002).

Several studies have shown that green manure and leguminous trees could improve soil fertility and increase crop yields (Abebe & Diriba, 2003; Vanlauwe *et al*., 2005; Sileshi *et al.*, 2008). However, they are not widely adopted and used in Ethiopia. One of the possible reasons could be the exotic origin of the plants species with farm level reluctance for adopting. The other reason is the limited effort made by researchers and extension personnel to identify and deploy them in the right niches (Wassie & Shiferaw, 2009).

Thus, there is need to identify fast growing, easy to propagate, nutrient rich and N-fixing trees and shrubs those can serve as excellent sources of green manure. To that effect, *Erythrina bruci* an N-fixing tree endemic to Ethiopia (Demil, 1994; Fassil, 1993) was chosen for this study. Leaves of *E. bruci* are commonly used as animal feed during dry season and its litter is excellent source to maintain soil fertility (Eyasu, 2002; SLU, 2006).

Aforementioned findings are however, felt insufficient. The information is scarce on the use of *E. bruci* for improving soil fertility. Therefore, this study was done to determine N, P and K contents *E. bruci* and application of its biomass alone or in combination with the inorganic fertilizers on the yield and yield components of wheat under southern Ethiopian conditions.

## MATERIALS AND METHODS

**Brief description of *E. bruci*:** *E. bruci* is a leguminous tree endemic to Ethiopia (Gillet, 1961; Thulin, 1989) with leaf symbiotic N-fixing characteristics (Legesse, 2002). It is adapted to grow in areas with altitude ranging from 1400 – 2600 masl. It fixes atmospheric nitrogen through its leaves (Fig. 1, Plate B) in contrast like angiosperms of Rubiaceae and Primulaceae (Miller, 1990; Legesse, 2002). Being fast growing tree reaching up to 6 m height within 3 months, *E. bruci* has a very important agro-forestry attributes such as, spreading leaves, source of large quantities of swiftly decomposable litters, vigorous re-growth, copious coppicing as well as rapid recovery after a spell of prolonged drought (Demil, 1994; Legese, 2002). Typical young *Erythrina bruci* trees grown as live fences are shown in (Fig. 1 Plate A). Farmers of Gedio area reported that its falling leaves are excellent of organic manure significance (SLU, 2006). It is propagated both by seed and cuttings. Farmers prune its branches and leaves to be used as animal feed at times of feed shortage. In the southern Ethiopia particularly in Wolaita, Kembata, Hadya, Gedio, Sidama and Guragie zones, *E. bruci* is grown abundantly as live fences, as farm boundary and inside farmlands as agro-forestry tree (Eyasu, 2002; SLU, 2006; Wassie & Shiferaw, 2009). Production of up to 50 kg of fodder biomass (Leave + twigs) per tree per year is potential of *Erythrina* spp (Na-songkhla, 1997). Assuming that *E. bruci* also produce 50 kg of biomass per tree per year, it is calculated that of 10 tones of biomass per year can be obtained from 200 trees.

**Determination of Nitrogen, Phosphorus and Potassium contents of *E. bruci* leaf and twig biomass:** Nitrogen, Phosphorus and Potassium contents of leaf and twig of *E. bruci* were determined as described in Mutuo and Palm (1999). Representative leaves (old & new) and twigs samples from randomly selected *Erythrina* trees were collected from nine location of southern Ethiopia from trees aged between 2–3 years for having more succulence, a principle for selection of green manuring crop. Three branches were selected from a total of 27 randomly selected trees: one in the lower, in the middle and upper canopy of each tree. Then all leaves and twigs were removed, mixed and a composite sample per tree was taken. Samples were air dried and milled to pass through 1 mm sized sieve. The processed samples were analyzed for N, P and K content at the National Soil Research Laboratory, Addis Ababa. Total N content was analyzed using micro-Kjeldahl's method and P and K contents were determined using dry ashing methods as described by Anderson and Ingram (1996).

**Field experiment:** A two year field experiment was conducted in southern Ethiopia during 2007 and 2008 cropping seasons at Kokate (Latitude: 6$^{o}$ 52'N and Longitude: 37$^{o}$ 48'E) at an altitude of 2156 masl with average annual rain fall of 1325 mm (Fig. 2) and mean maximum temperature of 22.5$^{o}$C. The soil is characterized as Dystric Nitisol having clay loam texture and pH of 5.8, total N of 0.215%, Available P of 3.2 ppm, OC of 2.15% and available K of 45.5 ppm (ARC Progress Report, 2005). The treatments consisted of a factorial combination of 3 levels of fresh *Erythrina bruci* biomass (0, 5 & 10 t ha$^{-1}$) and 3 levels of chemical fertilizers ($N_0P_0$, $N_{23}P_{20}$, $N_{46}P_{40}$ kg ha$^{-1}$ corresponding to 0, half & full doses of the recommended N & P fertilizers). The experiment was laid out in randomized complete block design (RCBD) with 3 replications.

The plot size was 4x4 m to which seeds of bread wheat (*Triticum aestivum* L.) variety Simaba were planted with row spacing of 20 cm at a seed rate of 150 kg ha$^{-1}$. The land was first ploughed with tractor mounted mold board-plough and subsequent land preparation and leveling was done by hand using local farm implements similar to hoe. The plot was planted with linseed the previous year. Planting dates for the 2007 and 2008 seasons were 24 and 25 of July, respectively. The same plots which were used in 2007 were again used in 2008 and each treatment was assigned to its respective plot. Fresh leave and twigs of *E. bruci* were collected from the near by live fences and farm boundary plants chopped and incorporated at a soil depth of 15 cm one month before planting of wheat for each rate of

**Fig. 1: *E. bruci* leaf showing N-fixing nodule, near Soddo town, 170 km south west of Addis Ababa, Ethiopia**

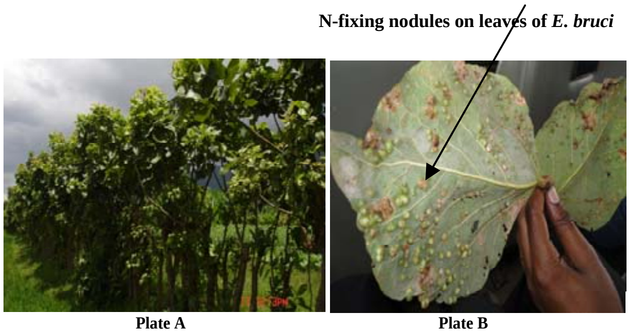
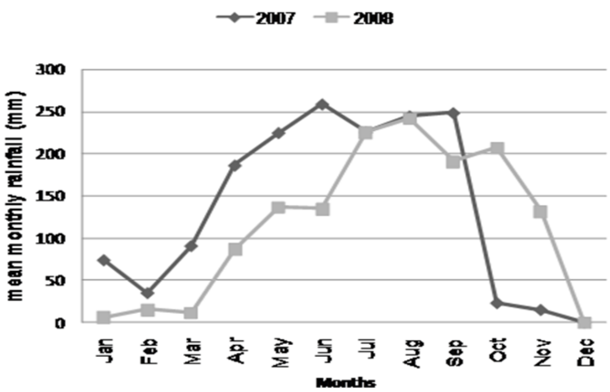



**Fig. 2: Monthly rainfall (mm) recorded at the experimental site at Kokate during 2007 and 2008**




biomass application. N was applied in the form of Urea (N= 46%) and P in the form of triple super phosphate (TSP) containing 20% P. Urea was applied, half at planting and after one month of planting. Broad leaf weeds were controlled by spraying plots with 2, 4-dichlorophenoxy acetic acid (2, 4-D) herbicide and grass weeds were controlled by hand weeding. Crops were harvested on 28 November in 2007 and 5 December in 2008.

Data on plant height, spike length, number of spikelets per spike, grain and straw yields were collected. The grain moisture content was adjusted to 12.4% before statistical analysis.The data were subjected to analysis of variance using the SAS system version 8.1 (SAS, 2000) and significance of means was established using least significant difference method (LSD).

**Economic analysis:** Mean grain yield data of two years (2007–2008) in selected treatments were used in the partial budget analysis (CIMMYT, 1988). The field price of 1 kg of wheat grain that farmers receive for sale of the crop was taken as 5.0 Ethiopian Birr (ETB) based on the market price of wheat grain at Soddo town near the experimental site, 390 km away from Addis Ababa. N was applied as urea and its price was 7.06 $kg^{-1}$ ETB. P was applied as triple superphosphate (TSP). Since TSP is not available in the market, the applied P was converted in to DAP equivalents and price of DAP was 9.33 birr $kg^{-1}$ ETB. The average labor cost incurred for incorporating 1.0 t $ha^{-1}$ of *E. bruci* biomass was 50 ETB.

The gross benefit was calculated as average adjusted grain yield (kg $ha^{-1}$) x field price that farmers receive for the sale of the crop (5.0 ETB $kg^{-1}$).

Total variable cost was calculated as the sum of all cost that is variable or specific to a treatment against the control. Net benefit was calculated by subtracting total variable cost from the gross benefit. The marginal rate of return (MRR) was calculated as the ratio of differences between net benefits of successive treatments to the difference between total variable costs of successive treatments. Treatments with higher cost and with lower net benefit than the previous successive treatments are indicated as dominated (D).

## RESULTS

**N, P and K contents of leaves and twig samples of *E. bruci*:** The results of chemical analyses of leaves and twig samples revealed that *E. bruci* has average contents of nitrogen, 4.83% (n= 9), phosphorus, 0.38% (n= 9), potassium, 2.24% (n=7).

**Effect on grain and straw yield of wheat:** Combined data analysis of the two seasons revealed that there was a highly significant (P =0.0001) difference among treatments in their effect on grain yield of maize (Fig. 3). Application of 5 and 10 t $ha^{-1}$ of *E. bruci* biomass significantly increased the grain yield of wheat by 82% and 127% over the control respectively. Similarly, application of the recommended dose of NP fertilizer ($N_{46}P_{40}$) has significantly increased the grain yield by 145% over the control. There was no statistically significant difference between plots that received sole application of *E. bruci* biomass at 10 t $ha^{-1}$ and recommended dose of fertilizers. However, the highest grain yield was obtained from plots that received combined application of *E. bruci* biomass + inorganic fertilizer applied at 10 t $ha^{-1}$+ $N_{23}P_{20}$, 5 t $ha^{-1}$+ $N_{46}P_{40}$ and 10 t $ha^{-1}$+ $N_{46}P_{40}$. These treatments increased the grain yield of wheat by 173, 190 and 227% over the control respectively. Inorganic fertilizers x biomass was non-significant for grain yield.

Seasons have significantly affected the grain a yield of wheat and that the highest grain yield (2.6 t $ha^{-1}$) was obtained during the first season (2007) against 2.3 t $ha^{-1}$ that obtained during the second season (2008).

Highly significant differences among treatments for straw yield of wheat at Kokate (Fig. 4) depict. *E. bruci* biomas applied at 5 and 10 t $ha^{-1}$ increased the straw yield by 47 and 106% with respect to control respectively. With regard to NP fertilizer, full recommended dose increased the straw yield significantly by 153% over the control. However, the highest straw yield was obtained from plots that received combined application of biomass and inorganic fertilizer. Combined applications of 10 t $ha^{-1}$ +

**Fig. 3: Effect of transferred biomass of *E. bruci* and inorganic fertilizer on grain yield of wheat over the two seasons at Kokate, Southern Ethiopia**

*Bars followed by the same letter (s) are not statistically different from each other

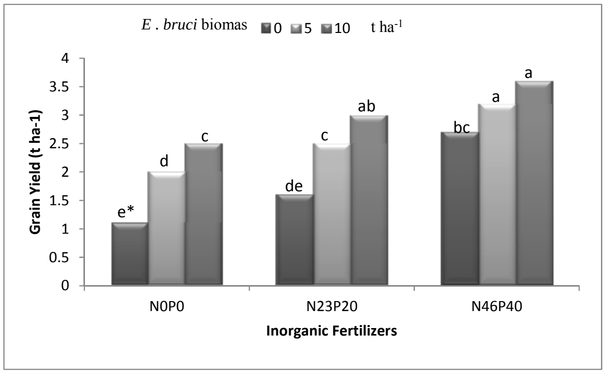
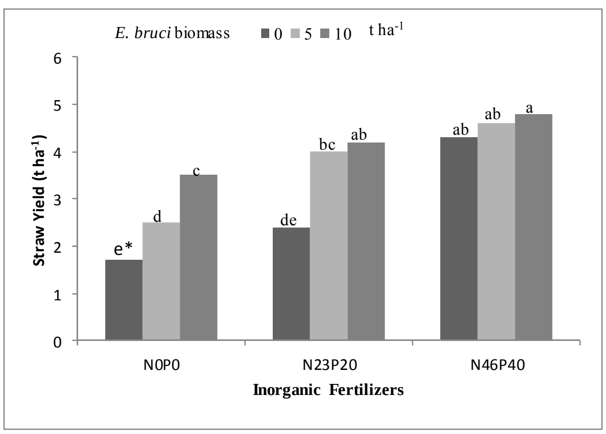



**Fig. 4: Effect of *E. bruci* biomass applied alone or in combination with inorganic fertilizer on straw yield of wheat over two of the seasons at Kokate, Southern Ethiopia**

*Bars followed by the same letter (s) are not statistically different from each other




$N_{23}P_{20}$, $N_{46}P_{40}$ + 5 t $ha^{-1}$ and $N_{46}P_{40}$ + 10 t $ha^{-1}$ biomass increased the straw yield by 147, 170 and 182% over the control, respectively. There were non significant differences among treatments for straw yield. For straw yield Treatment x season was non-significant.

**Effect on plant height, spike length and number of spike:** Plots that received biomass resulted in significantly increased height, spike length and number of spikes of wheat plants grown in them as compared to the control (Table I). However, the highest plant height, spike length and number of spikes were achieved with the application of biomass at the rate of 10 t $ha^{-1}$. Application of inorganic fertilizers have also significantly increased plant height, spike length and number of spikes and the highest mean plant height, spike length and number of spikes were obtained from plots that received the recommended doses of fertilizer. Season have also significantly affected plant height, spike length and number of spiklet/spike and the highest plant height, spike length and number of spikes/spike were obtained during the first season than the second.

**Table I: Effect of *E. bruci* biomass and fertilizer on plant height, spike length and number of spiklets per spike at Kokate over the two years**

| Treatment combination | Plant height (cm) | Spike length (cm) | No. of spikelet/spike |
|---|---|---|---|
| ***E. bruci* biomass (t $ha^{-1}$)** | | | |
| 0 | 78c | 7.8c | 25.5c |
| 5 | 87b | 8.5b | 29.7b |
| 10 | 90a | 9.0a | 33.2a |
| **Inorganic fertilizers** | | | |
| 0 | 79.2c | 7.25c | 25.0c |
| $N_{23}P_{20}$ | 84.9b | 8.20b | 29.4b |
| $N_{46}P_{40}$ | 87.8ab | 8.60a | 31.8a |
| **Season** | | | |
| 2007 | 89.7a | 8.5a | 30.0a |
| 2008 | 80.0b | 8.1b | 28.0b |
| **Biomass** | ** | ** | ** |
| **Fertilizer** | ** | ** | ** |
| **Season** | ** | ** | ** |
| **CV (%)** | 5 | 4.8 | 8 |

**Significant at 0.01 probability level, respectively

**Economic analyses:** Partial budget analysis revealed that the highest net benefit (12610.5 birr) with acceptable marginal rate e of return were obtained from 10 t $ha^{-1}$ *E. bruci* biomass + half of the recommended NP fertilizer (Table II). The next highest net benefit (10570 birr) was obtained from *E. bruci* biomass applied at 10 t $ha^{-1}$.

## DISCUSSION

*E. bruci* has higher N, P and K content when compared to most of the leguminous crops and trees (*Leucaena*, *Calliandra* spp. *Gliricidia septum* & *Cassia spectabilis*) (Maclean *et al*., 1992; Kahsay & Thotill, 1995; Gachene *et al*., 1999). Significantly higher yield and other variables of wheat obtained with *E. bruci* biomass incorporated in to the soil compared with the control in this study could probably be due to the availability of nutrients to the crop from the nutrient-rich biomass of *E. bruci* and its N-fixation characteristics. This is in agreement with reports indicating that N-fixing biomass from leguminous trees incorporated into the soil as green manure greatly improve yield and yield components of several crops (Gachene *et al*., 1999; Mugwe *et al*., 2007). According to Abebe and Diriba (2003), biomass of *Cajanus cajan* applied at a rate of 4 t $ha^{-1}$ increased the grain yield of maize by over 86% compared to the control. It was further found in this study that combined application of *E. bruci* biomass and NP fertilizers gave significantly higher yield and yield components of wheat compared to either biomass or inorganic fertilizer applied alone. This is in agreement with earlier reports (Vanlauwe *et al*., 2005; Teklu *et al*., 2009; Wassie *et al*., 2009). Even though organic inputs are the sources of macro and micro

**Table II: Partial budget analysis of the treatments.**

| Partial budget | Treatment | | | |
|---|---|---|---|---|
| | **Control** | **Erythrina (10 t ha$^{-1}$)** | **Erythrina 10 tha$^{-1}$ + Half NP (23/20 kg ha$^{-1}$)** | **NP (46/40 kg ha$^{-1}$)** |
| Average yield (kg ha$^{-1}$) | 10.5 | 24.6 | 30.4 | 27.3 |
| Adj. yield (kg ha$^{-1}$) | 9.45 | 22.14 | 27.36 | 24.57 |
| Gross benefit birr ha$^{-1}$ | 4725 | 11070 | 13680 | 12285 |
| N | 0 | 0 | 353 | 706 |
| P | 0 | 0 | 466.5 | 933 |
| labor for Erythrina biomass incorporation | 0 | 500 | 250 | 0 |
| TVC | 0 | 500 | 1069.5 | 1639 |
| Net benefit ETB ha$^{-1}$ | 4725 | 10570 | 12610.5 | 10646 |
| **MRR (%)** | | **1169** | **358** | ***D** |

*Dominated

nutriments leading to overall improvement of the physical and chemical characteristics of the soil, they are unable to sufficiently replenish the soil with nutrients particularly P and K. The fertilizer value of organic inputs also varies with the quality, timing and rate of application. In addition they, tend to have higher labor requirement (Place *et al*., 2003). Besides the adverse effects of some types of inorganic fertilizers, fertilizers recovery efficiency of crops is often low (Rowell, 1994; Stayanarayana *et al*., 2002). Thus, combined applications of organic and inorganic nutrient sources help ameliorate the short comings of sole application of either input. Integrated application of organic and inorganic nutrient sources result in synergistic effects on yield (Vanlauwe *et al*., 2005; Akinnifesi *et al*., 2007). Nutrients applied as inorganic fertilizers along with organic sources are also retained for long period of time in the soil than applied alone (Ravishankar *et al*., 2000). For example, leaching and denitrification loss of nitrogen was very low when inorganic N-fertilizers were applied along with farm yard manure (Taye *et al*., 1996). Similarly, Kumar *et al*. (1999) based on the results of pot experiment reported the large amount and more consistent production of $NH_4^+$-N and $NO_3$-N when organic and inorganic fertilizers are applied together than inorganic sources alone.

*E. bruci* biomass x fertilizer was not significant for grain, straw and yield components of wheat suggesting that the change in the level of *E. bruci* biomass did not alter the effect of fertilizers or vice-versa. This is in agreement with the finding of Abebe and Diriba (2003).

The highest yield and yield components of wheat were obtained during the season of 2007 than 2008. This is probably due to the higher amount of rain fall received during critical growth period of wheat that is September, 2007 than that received in the same period in 2008 (Fig. 2).

## CONCLUSION

Results proved *E. bruci* biomass as a rich source of N, P and K contents. *E. bruci* biomass incorporated in the soil at the rate of 10 t ha$^{-1}$ resulted in grain and straw yields of wheat comparable to that obtained with recommended dose of fertilizer for wheat at Kokate area of southern Ethiopia. Application of *E. bruci* biomass and half of the recommended doses of inorganic fertilizers gives significantly superior yield of wheat over each of the source applied alone. Economic analysis of the data have showed the highest net benefit and marginal rate of return from combined application of 10 t ha$^{-1}$ of *E. bruci* and half dose of NP fertilizers followed by biomass applied at 10 t ha$^{-1}$ alone. Therefore, it is recommended that *E .bruci* biomass should be used as green manure alone or along with decreased doses of inorganic fertilizer to soil fertility improvement for enhanced crop yield in Ethiopia.

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