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The Effects of Application of *Erythrina bruci* Biomass and Inorganic Fertilizers On Wheat Productivity in Southwestern Ethiopia.

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Abstract

Soil fertility depletion is emerging as a serious challenge causing low crop yields and food insecurity in Ethiopia. An experiment was conducted in two cropping seasons 2016 to 2018 to investigate the effects of the application of *Erythrina* biomass and nitrogen fertilizer on soil properties and wheat yields in southwestern Ethiopia. Treatments were the recommended N and P fertilizers, 50% of the standard rate of *Erythrina* + 50% of the recommended N, 25% *Erythrina* + 75% N, 75% of the standard rate of *Erythrina* + 25% of the standard rate of N, 100% of the standard rate of *Erythrina*, and 50% of the standard rate of *Erythrina*, and without fertilizer as the control. The experiment was arranged in a randomized complete block design with three replications. Application of *Erythrina* and nitrogen fertilizer increased soil organic carbon (OC), total nitrogen (TN), and cation exchange capacity (CEC) compared to before fertilizer application or the control. Plots amended with 25% *Erythrina* + 75% of the recommended N provided the highest above ground biomass (8.98 $t.ha^{-1}$) and grain yield (3.453 $t.ha^{-1}$) and it was higher than the 100% chemical fertilizer treatment. Conversely, the lowest above ground biomass (5.44 $t.ha^{-1}$) and grain yields (1.958 $t.ha^{-1}$) were obtained from the control. Our study demonstrated that an integrated nutrient management which combines organic and chemical fertilizer can improve soil properties and increase wheat yield in the highlands of southwestern Ethiopia.

Keywords: organic amendment, soil properties, organic fertilizer, leguminous trees

Introduction

Soil fertility depletion is emerging as a serious challenge causing low crop yields and food insecurity in Ethiopia. The decline in soil fertility is the main challenge to crop production in the South Region. Continuous cultivation, inadequate application of organic nutrient sources, and soil erosion account for reduced soil fertility (Tamado and Mitiku, 2017). Organic fertilizers can improve the physico-chemical properties of the soil (Abiy, 2018). The use of organic fertilizers such as farmyard manures, compost, green manures, and biomass of leguminous trees is an alternative way to improve soil fertility and soil physical properties (Abebe, 2018). Wassie (2012) reported that application of *Erythrina* biomass at 10 $t.ha^{-1}$ + half of the recommended rate of N and P, or 23 $kg.ha^{-1}$ of N and 23 $kg.ha^{-1}$ of P increased wheat grain yield by 189%. In addition, the cost of inorganic fertilizer could be reduced by half using *Erythrina* biomass as organic supplement while obtaining superior yield of wheat than either source applied alone.

Erythrina is one of the locally available trees and can be used as the source of organic matters for the crop. *Erythrina* is grown as live fence and farm boundary plant at Chena Woreda of Kaffa Zone. It is a legume species, an N-fixing, easily propagate, nutrient rich leguminous tree and can be easily exploited as source of organic source fertilizer by small scale farmers for crop production and soil fertility amendment. Application of inorganic fertilizers has been promoted to overcome low soil fertility and reduced crop yields. The raising costs of fertilizers with lack of financial resources farmers limits the required use of inorganic fertilizers for optimum yield. Moreover, the efficiency of the chemical nitrogen fertilizers is very low in Ethiopia, and it varies with crops, soil types, and management practices. Therefore, it is important to study if the application of organic in combination with inorganic fertilizers can improve soil fertility, increase nutrient use efficiency and crop yield.

Several studies have shown that green manure and leguminous trees could improve soil fertility and increase crop yields. However, this practice has not widely adopted and used in Ethiopia. One of the possible reasons could be the exotic origin of the plants species with farm-level hesitancy 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 et al., 2009). Leaves of *Erythrina* are commonly used as animal feed during dry season and its litter is excellent source of organic matter that can maintain soil fertility (Eyasu, 2002). However, the information is scarce on the use of *Erythrina* for improving soil fertility. So, it is essential to study the effect of application *Erythrina* biomass alone or in combination with the inorganic fertilizers on the yield of wheat in the south region to determine the effects of *Erythrina* biomass and inorganic fertilizers for wheat production.

Material and Methods

Description of Study Area

The experiment was conducted at Chena District of Kaffa Zone, South-Western Ethiopia, in 2016-2018 main cropping seasons, i.e. from July to November. The site in Chena district is located at latitude of 7°05.67´ N, longitude of 35°42.989´ E and altitude of 2135 meters above sea level. The rainfall pattern of this area is characterized by bimodal distribution with small rainy season 'Belg' (March-June) and main rainy seasons 'Meher' (July-November). The average annual rainfall data from Wushwush Meteorological Station was 1367 mm. The maximum temperature of cropping season varied from 22.1 to 26.6^{0}C; the minimum temperature varied from 10.0 to 13.1^{0}C.

The soil analysis of the study sites before sowing of the crop showed that the soil texture of the experimental fields was clay loam with medium CEC, low organic carbon content, total N, and available P (Table 1).

Experimental Design and Experimentation

The experiment was conducted in 2016-2018 on the farmers' field of Chena Woreda of Kaffa Zone. Wheat variety "Daphe" was used as a test crop. A cultural practice was carried out based on the recommendation of the crop (Wasihun, 2022). The experiment consists of seven treatments: control (no fertilizer), recommended N and P (46 kg.ha^{-1} of N, 46 kg.ha^{-1} of P), 50% of the recommended rate of *Erythrina* + 50% of the recommended rate of N, 25% of the recommended rate of *Erythrina* + 75% of the recommended rate of N, 75% of the recommended rate of *Erythrina* + 25% of the recommended rate of N, 100% of the recommended rate of *Erythrina* and 50% of the recommended rate of *Erythrina.* The experiments was laid out in randomized block design with three replication (plot). Each plot was 5m x 5m (25 m^2) with the net harvestable area of 4 m x 4 m (16 m^2) having 1 m space between plots and 1 m between blocks. Rows were being spaced 0.2 m interval. All data was subjected to analysis of variance. Sources of N and P was urea and triple super phosphate (TSP). Half dose of P and N were applied at planting and the remaining half dose was applied 35 days later. *Erythrina* biomass consisting of young leaves and twigs were chopped into small

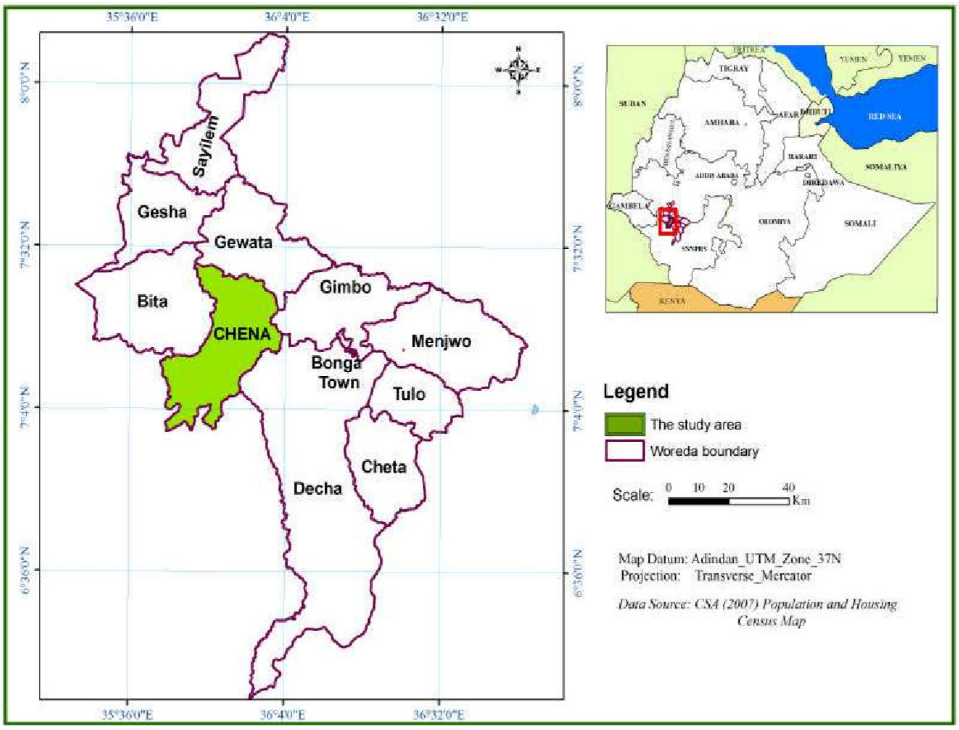

Figure 1. Geographical location of the study area at Chena District of Kaffa Zone, South-Western Ethiopia.

Table 1. Initial soil physicochemical characteristics of the experimental sites.

Soil parameters	Value	Rating	References
Textural class	Clay loam	-	
pH	6.03	Slightly acidic	Hazelton and Murphy (2007)
Organic carbon (%)	1.52	Low	Hazelton and Murphy (2007)
Total N (%)	0.11	low	Tekalign (1991)
Available P (mg.g^{-1})	7.10	Low	Tekalign (1991)
CEC (cmol.kg^{-1})	18.05	Medium	Landon (1991)

pieces to enhance decomposition. The chopped parts were then incorporated into the soil one month before planting of testing crop. A total of 15 composite soil samples from 15 spots, collected from 0-20 cm soil depth, were taken using auger before planting for analysis of texture, pH, CEC (cation exchange capacity), OC (organic carbon), total N (total nitrogen), and the available P.

Erythrina Nutrient Analysis

Erythrina leaves and twigs were sampled from six randomly selected healthy trees for nutrient analysis. Three branches were selected, the lower, the middle and the upper tree canopy. The samples were mixed and composite samples were analyzed for N, P and K content. Samples were air dried and milled to pass through 1 mm diameter mesh size. Total N content was analyzed using micro-Kjeldahl's method and P and K contents was determined using dry ashing methods that described by Anderson and Ingram (1996). The young twigs and leaves of *Erythrina bruci* contain 4.83% N, 0.38% P and 2.24% K.

Plant Growth Measurements

Agronomic parameters including tiller number, grain yield, above-ground biomass, plant height, spike length and thousand seed weight were measured. The data were subjected to analysis of variance using the SAS system version 9.4 (SAS, 2000) and the significance of means was established using the least significant difference method (LSD).

Results and Discussion

Soil Analysis Results

The soil properties after the application of treatments was shown in Table 2. The soil chemical properties (organic carbon, total nitrogen, available phosphorus, and CEC had changed compared to before planting. Integration of leguminous tree and inorganic fertilizer increases both CEC and organic carbon in the soil. The changes in CEC and organic carbon indicated that *Erythrina* biomass was decomposing and contributed nutrients to the soil.

Effects of Erythrina Biomass and Chemical Fertilizer Application on Wheat Yield and Yield Components

The effects of *Erythrina* biomass on wheat yield and yield component in both years are significant ($P < 0.05$, Table 3). The maximum grain yield (3.453 t.ha^{-1}), above ground biomass (8.98 t.ha^{-1}) and tiller number (8.22) was obtained by the application of 25% *Erythrina* with 75% N as compared to control that gives the lowest yields (Table 3). Application of 100% *Erythrina* gives the highest spike length and

Table 2. Soil properties after *Erythrina* + chemical fertilizer application

Treatment	pH-H_2O	OC (%)	TN (%)	CEC (me.100g^{-1})	Av.P (ppm)
Control	5.05	3.57	0.31	18.4	4.21
Recommended NP	5.86	4.81	0.42	25.6	3.67
50% *Erythrina* + 50% N	6.05	5.00	0.42	23.2	5.05
25% *Erythrina* + 75% N	5.76	4.28	0.37	21.8	4.68
75% *Erythrina* + 25% N	5.93	4.95	0.42	24.0	4.87
100% *Erythrina* N	6.02	5.47	0.48	25.8	4.11
50% *Erythrina* N	5.77	3.57	0.31	20.4	3.18

Note: OC=organic carbon, TN=total nitrogen, CEC=cation exchange capacity, Av.P =available phosphorus; 100% *Erythrina* = 4 t.ha^{-1} fresh biomass.

Table 3. Effect of *Erythrina* and chemical fertilizer on yield and yield component on wheat

Treatments	PH (cm)	TN	SL (cm)	TSW (g)	Above ground biomass ($t.ha^{-1}$)	Grain yield ($t.ha^{-1}$)
Control	75.62b	4.75c	7.30b	35.32d	5.44c	1.958c
Recommended NP	78.77ab	6.77b	7.85a	42.42ab	7.78ab	2.887b
50% *Erythrina*+ 50% N	80.47a	6.90ab	7.77a	42.03ab	7.96ab	2.963ab
25% *Erythrina*+ 75% N	78.28ab	8.22a	7.52ab	37.80cd	8.98a	3.453a
75% *Erythrina* + 25% N	76.53b	6.73b	7.66ab	41.62ab	7.67ab	3.021ab
100% *Erythrina*	80.68a	6.52b	7.78a	40.40bd	7.68ab	2.993ab
50% *Erythrina*	77.60ab	6.03bc	7.65ab	44.37a	7.06ab	2.766b
LSD	1.83	0.72	0.22	1.98	0.641	0.274
CV%	3.68	17.41	4.55	7.69	13.47	15.09

Note: Means followed by the same letter (s) within the column are not significantly different according to LSD at $P \leq 0.05$. PH= plant height, TN= tiller number, SL= spike length, TSW = one-thousand seed weight. The treatment of 100% *Erythrina* equals 4 $t.ha^{-1}$ *Erythrina* biomass; the recommended NP is 46 kg $N.ha^{-1}$ or 100 $kg.ha^{-1}$ Urea, and 46 $kg.ha^{-1}$ P_2O_5 or 100 $kg.ha^{-1}$ TSP.

plant height as compared to control. The increase of plant height and spike length in response to the increasing N from both *Erythrina* and nitrogen may be accredited to the increase of availability of N that enhanced wheat vegetative growth. Our results agree with Moniruzzaman et al. (2009) who recorded maximum plant height of French snap bean from the application of 120 kg $N.ha^{-1}$ and the minimum height was recorded from the control treatment. Another finding conducted by Mostafa and Zohair (2014) demonstrated that application of 100 kg $N.ha^{-1}$ and chicken manure to snap bean in sandy soil significantly increased plant height by scoring the highest value (22.8) as compared to control (11.7). On the other hand, one-thousand seed weight (TSW) was significantly affected at ($P<0.05$) by the application 50% *Erythrina* with nitrogen. Maximum value of the one-thousand seed weight (44.37 g) was recorded from the application of 50% *Erythrina* as compared to control treatment (Table 3). The result agrees with Hossain et al. (2018) who reported that an application of combined organic (5 $t.ha^{-1}$ bio-slurry) and inorganic fertilizers increasing one-thousand seed weight in treated plots over the control/untreated plots.

Conclusion

Our study demonstrated that application of Erythrina biomass at 25% of the recommended dose combined with 75% nitrogen (34.5 $kg.ha^{-1}$ N) resulted in the highest yield and yield components, and it was higher over the 100% chemical fertilizer treatment. These results showed that the requirements for the chemical nitrogen could be reduced by the application of *Erythrina* biomass. Therefore, application of 1 $t.ha^{-1}$ *Erythrina* biomass with 34.5 $kg.ha^{-1}$ N inorganic nitrogen can be suggested for wheat production in Chena District of Kaffa Zone, South-Western Ethiopia. Future studies should be conducted across similar agro-ecologies to potentially reduce the use of chemical fertilizer without reducing yields.

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