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## Evaluation of Alternative Break Crops in Rotation with Bread Wheat (*triticum aestivum* L.) in South-Eastern Ethiopia

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### ABSTRACT

Crop rotation could be a possible intervention to resolve multifaceted problems of monoculture. In recent years, there is a concern about soil depletion caused by intensive farming. In crop rotation legume crops, which capture atmospheric nitrogen and “fix” it into forms available to plants will increase soil fertility. Faba bean (*Vicia faba* L.), rapeseed (*Brassica napus* L.), oat (*Avena sativum* L.) and vicia (*Vicia dasycarpa* Ten.) forage mixture were considered as a break/precursor crops. The result showed that most profitable cropping sequence was faba bean grown in a 3 year cycle with 2 crops of wheat (Amanuel et al., 1994). Thus, searching for promising and alternative break crops for wheat based rotation could increase productivity and maximize profit. Adaptation trial around Bekoji showed that sweet lupine seems an option in tolerating acidity where faba bean is found susceptible. Thus, the objectives of this study was to evaluate alternative break crops on yield and yield components of the succeeding wheat and soil fertility maintenance in the rotation scheme. Thus, this study was executed for three consecutive years from 2017- 2019 main cropping seasons at Kulumsa, Bekoji and Asasa Arsi zone, South-Eastern Ethiopia to evaluate advantage of alternative break crops on yield and yield components of the succeeding wheat and its effect on soil fertility maintenance in the rotation scheme. The experiment was laid out in randomized block design with five replications. The treatment include: wheat-sweet lupine-wheat-wheat-wheat in year one (2017), sweet lupine-wheat-wheat faba bean-Ethiopian mustard in year two (2018) and wheat-wheat-wheat-wheat-wheat in the third year (2019). These leguminous crops have improved physico-chemical properties of soil. Plant nutrients of soil on which legumes were grown were increased. This improvement of soil properties by leguminous crops has resulted in higher yield of wheat than plots on which wheat was grown after wheat. Although non-significant, the third year Bekoji and Asasa combined analysis of variance revealed that the highest wheat grain yield (4197kg/ha) was obtained at sweet lupine-wheat-wheat followed by wheat-faba bean-wheat (4003kg/ha). However, plant height was significantly ( $P<0.05$ ) affected by rotational crops effect. The tallest plant height of wheat (105.0cm) was recorded from wheat-Ethiopian mustard-wheat treatment. From this study, sweet lupine-wheat-wheat followed by wheat-faba bean-wheat with proper agronomic packages could be forwarded as a temporary recommendation in Asasa, Bokoji and Kulumsa areas and in areas with similar agro ecologies.

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### Introduction

Sustainability of crop production could be based upon efficient use of growth resources coupled with environmentally friendly agricultural technologies. Cereal monoculture in the wheat belt of Ethiopia resulted in the development of resistant pests, especially weeds and diseases. Crop rotation could be a possible intervention to minimize this problem [1]. It is the sequencing of different crops over time on the same field to maintain or build soil organic matter, to control pests, to manage and conserve nutrients, and to protect soil against erosion [2]. Crop rotation represent a systems approach to crop production research, enabling available natural resources to be preserved and more efficiently utilized [3].

Current and future agronomic challenges of climate change, sustainable crop production, and food security for a growing world population is becoming increasingly important to evaluate the effects of different crop rotations on the stability of crop yields

and profitability [4, 5]. It is broadly recognized that crop rotation often increases the crop yield [6] and provides for more sustainable crop production [7]. Crop rotation helps develop resilient crop production systems for the future [8].

Crop rotation can also support ecological intensification, i.e., maximizing productivity per unit area while minimizing environmental impacts [9]. Crop rotation has many agronomic, economics and environmental benefits. In recent years, there is a concern about soil depletion caused by intensive farming [10]. In crop rotation legume crops, which capture atmospheric nitrogen and “fix” it into forms available to plants will increase soil fertility [11]. Crop rotation also affects the presence of host-specific pests by disturbing their life cycle. Pest management is based on prevention, in which the crop rotation aims to create unfavorable conditions for the pest and favorable conditions for the crop [12].

Accordingly, several crop rotation experiments were conducted around the country to select suitable crops and cropping sequence

with different objectives (maximize yield, disease management, weed control, and soil fertility management ...). Long year crop rotation trials were conducted in south eastern Ethiopia using different crops and sequences. Faba bean (*Vicia faba* L.), rapeseed (*Brassica napus* L.), oat (*Avena sativum* L.) and vicia (*Vicia dasycarpa* Ten.) forage mixture was considered as a break/precursor crop. The result showed that most profitable cropping sequence was faba bean grown in a three-year cycle with two crops of wheat [1]. Thus, searching for promising and alternative break crops for wheat-based rotation could increase productivity and maximize profit. For instance, GIC-Giz- Ethiopia used sour lupine (*Lupinus angustifolius*) as a cover crop in different tillage systems at Kulumsa on-station site. They found that lupine is best suited as cover crop to increase yield and fertility status of the soil.

Traditionally, the sour lupine is used for different purposes such as alcoholic beverage in northern Ethiopia, around Gojam (named as Gibto). The release of sweet lupine varieties could be considered as source of income and diet to resource poor farmers besides to increased soil fertility. In addition to human food and rotational crop for soil fertility maintenance, and could also be used as additional source of livestock feed [13]. Adaptaion trial around Bekoji showed that sweet lupine seems an option in tolerating

acidity where faba bean is found susceptible. Thus, the objectives of this study were to evaluate alternative break crops on yield and yield components of the succeeding wheat and soil fertility maintenance in the rotation scheme.

**Material and Methods**

**Description of the Study Area**

The experiment was conducted under rain fed condition in Arsi zone, southeastern Ethiopia at three sites of Kulumsa Agricultural Research Center (Kulumsa, Bekoji and Asasa) for three consecutive years (2017-2019). However, due to change of experimental place at Kulumsa, the experiment will be completed in 2020. It is located in Gora silingo kebele, Tiyo district of Arsi Zone, Oromia Regional State, Southeastern Ethiopia (Figure 1). The experimental site is located at 8°01’N latitude and 39°09’E longitude, 167 km southeast of Addis Ababa at altitude of 2200 meters above sea level. It receives average annual rainfall of 809.2 mm and has a uni-modal pattern rain fall. The peak season of the rain fall is from July to August. The average annual minimum and maximum temperatures are 9.9 and 23.1 °C, respectively [14]. The soil type is luvisol/eutric nitosols with a good drainage system. It contains 5.5% organic matter, 0.25% nitrogen and its pH is 5.5-6.0 [15].

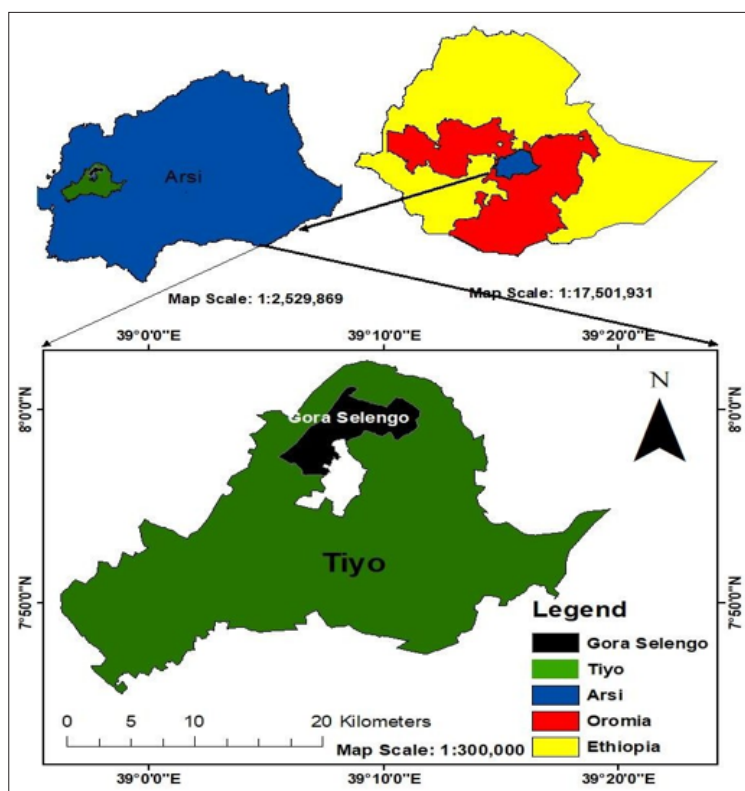


Figure 1: Location Map of the Kulumsa

**Experimental Materials**

Bread wheat variety, King bird was used in the experiment. Faba bean (Degaga) and Ethiopian mustard (Yellow Dodola variety) was used.

Table 1: Sources of Experimental Materials

Crops(variety)	Source
wheat (King bird)	Kulumsa Agricultural Research Center
Faba bean (Degaga)	Kulumsa Agricultural Research Center
Ethiopian Mustard (Yellow Dodola)	Holeta Agricultural Research Center

**Treatments and Experimental Design**

The experiment was laid out in randomized block design with five replications in each site. The treatment include: wheat-sweet lupine-wheat-wheat-wheat in year I (2017), sweet lupine-wheat-wheat-faba bean-Ethiopian mustard in year II (2018) and wheat-wheat-wheat-wheat-wheat in the III year (2019). The sequence of the crops in each year indicates the replication.

### Experimental Procedures

The field was ploughed by disc plough and harrowed using tractor before planting in the first year. But during second and third year the field was ploughed by oxen drawn equipment to avoid mixing of soil from different plots. Then it was leveled manually using hand tools. Both faba bean and wheat were planted simultaneously. Recommended seed rate of wheat (150kg/ha-1) and faba bean (200kg/ha-1) was used. Seed source for both faba bean and wheat was Kulumsa Agricultural Research Center. The crops were planted in row in which the inter row spacing for faba bean and wheat was 40cm and 20cm respectively. The experiment was conducted in permanent plots keeping the cropping sequence. The plot size was 10.4 m<sup>2</sup> (4 m long and 2.6 m wide) with net harvestable area of 10.4 m<sup>2</sup>. The seed was drilled by hand at light depth. The distance between plots was 1m. The rest agronomic practices (weeding, harvesting and threshing) was done as per the recommendations.

### Soil Sampling and Analysis

Soil samples were collected from 0-30 cm depth per plot to obtain representative composite soil samples. The samples were air-dried, ground and sieved through a 2mm sieve and made ready for analysis [16]. Soil samples collected were analyzed for pH, organic matter, organic carbon, total nitrogen and available phosphorus before planting and after harvest. The pH of the soil was measured in the supernatant suspension of a 1: 2.5 soil to water ratio using a pH meter by potentiometer method [17]. Organic matter was determined by wet oxidation method as described by [18]. Available P was determined by method [19]. Total nitrogen was determined using Kjeldahl method as described by [20].

### Data Collected

#### Growth, Yield, Yield Components and Quality Parameters

**Plant Height (cm):** was measured from the ground level to the tip of spike at physiological maturity from randomly selected 10 plants per plot.

**Thousand Kernel Weight (gm):** The weight of 1000 kernels was

determined by carefully counting the grains, adjusting to 12.5% moisture content and weighing them using a sensitive balance.

**Biological Yield (kg/ ha):** above ground biomass per net plot was determined and converted to hectare.

**Grain Yield (kg ha-1):** grain yield was obtained from each plot to estimate grain yield in kg ha-1. It was weighed and adjusted to 12.5%, 7%, 10% and 10% moisture content for wheat, rapeseed, faba bean and lupine, respectively.

Grain yield (adjusted at standard moisture content) = Grain yield \* ((100-%MC)/(100-12.5)). Grain moisture Harvest Index (HI%): was calculated on a plot basis, as the ratio of dried grain weight adjusted to 12.5% moisture content to the dried total above ground biomass weight and multiplied by 100.

**Hectoliter or Test Weight (kg hl-1):** was determined as the mass of grain to be contained on a standard hectoliter apparatus on dockage free basis as described in Method No 55-10 [21].

### Data Analysis

Data collected from this experiment was subjected to analysis of variance using Statistix software [22]. Mean separation was carried out using least significant difference test at 5% level.

### Results and Discussion

#### Soil Physico-Chemical Properties of the Experimental Site

The result of soil analysis before planting showed that the soil had a pH value of 4.79 ppm (very strongly acidic), organic carbon 2.44 and organic matter 4.21, (medium organic matter content according to rate) [23]. Total nitrogen 0.23% (medium total nitrogen as per and soil available phosphorus 0.58 (low level of available phosphorus as per) [24-25]. Soil physico-chemical properties of the experimental site after harvesting showed that all parameters analyzed were better on sweet lupine field compared to wheat field. For instance available phosphorus increased from 1.09 (ppm) to 2.13 (ppm), total nitrogen from 0.22% to 0.24% (Table 1). This is obviously known that legume crops can fix atmospheric nitrogen into forms available to plants by the help of rhizobium bacteria. Certain legume crops, including lupine, mobilise soil-bound phosphorus (P) through root exudates. The changes in the rhizosphere enhance phosphorus availability to these crops, and possibly to subsequent crops growing in the same soil [26]. also found that crop rotation has improved the soil organic carbon, total nitrogen, and available phosphorus.

**Table 2: Physico-Chemical Analysis of the Soil at Bekoji Substation in 2017 Cropping Season**

Before planting					
	pH	P	N	OC	OM
	4.79	0.58	0.23	2.44	4.21
After harvesting					
Wheat	5.20	1.09	0.22	1.95	3.36
Sweet lupine	5.33	2.13	0.24	2.88	4.97

N.B: P=available p (ppm) N=total nitrogen (%) OC=Organic carbon (%) OM=Organic matter (%)

### Yield Components and Yield

Effect of rotational crops in wheat based rotations in 2017 main cropping seasons at Kulumsa, Bekoji and Asasa areas showed that grain yield, above ground biomass and harvest index were not affected by neither locations nor rotational crops (Table 2). However, hectoliter weight (HLW) as quality indicating parameter was significantly (P<0.05) affected by location effect. The difference among Hectoliter weight with locations might be associated with genetic potential of the variety with respect to environmental effect (Table 2).

**Table 3: Effect of Rotational Crops on Yield and Yield Components of Bread Wheat based Rotations Combined Over Locations in 2017 Main Cropping Seasons at Kulumsa, Bekoji and Asasa Areas**

Treatment	Grain yield (kg/ha)	Above ground biomass (kg/ha)	Harvest Index (%)	Hectoliter weight (kghl <sup>-1</sup> )
Location				
Kulumsa	3756	8886	42.2	76.6a
Bekoji	3728	9263	37.4	43.9b
Asasa	3475	8810	42.5	47.6b
LSD	ns	s	ns	10.9*
Rotational crops				
Wheat	4119	9401	43.9	53.9
Wheat	2946	7678	38.9	59.2
Sweet lupine	3613	9159	40.1	63.0
Wheat	3737	9349	40.1	52.5
Wheat	3850	9344	40.5	51.8
LSD	ns	ns	ns	ns
CV (%)	10.86	14.74	10.34	13.32

Means followed by the same letter in a column are not significantly different at  $P < 0.05$ .

Though kingbird is rust resistant and early maturing wheat variety released for low and mid altitude area like Asasa and Kulumsa, its performance in the highland areas such as Bekoji showed its wide agro ecological adaptation. Previous field history of the trial site was cereal. Thus, yield increase could be expected in the subsequent rotational crops and years. Nevertheless, at Kulumsa, the permanent trial site was changed after 2018, so that the experiment was reinitiated in another site of the center to be completed in 2020. Sweet lupine is an edible and moderately resistant to acidic pH, which might be used interchangeably with faba bean in rotation, and also as source of protein for resource poor farmers. Though the pH range in crop production lies between 4.7 to 7.5, Bekoji is noted for its acidic pH. The inclusion of sweet lupine contributed to modify the soil pH (from 4.79 before planting to 5.33 after harvesting) (Table 2). This might be possibly due to proper distribution of rainfall at optimum condition and thereby decomposition of crop residues helps availability of nutrients and survival of beneficial microorganisms to amend the pH and increase in P, N, OC, and OM in the area. Though this trend was observed in wheat planted field, the same facts could be considered as an attributing factor. In fact, the result of 2018 and 2019 main cropping season soil analysis could be considered for further conclusion.

The rotational crops after 2017 main cropping seasons at Bekoji and Asasa indicated variable responses with respect to the control and main rotational crops in 2018. Grain yield, above ground biomass and harvest index were not significantly different for rotational crops and year effect (Table 2). However, plant height was significant ( $P < 0.05$ ) to rotational crops. Ethiopian mustard (EM) is a heavy nutrient feeder oil crop that can suppress weeds and improve soil structure for its deep rooting nature and have longer decomposition time. Higher plant height in EM related due to its inherent genetic potential to use growth resources. Faba bean and sweet lupine are known nitrogen fixer for subsequent crops. However, faba bean is susceptible to acidity unless otherwise sown in treated soil.

**Table 4: Effect of Rotational Crops on Yield and Yield Components of Bread Wheat based Rotations Combined Over Locations in 2018 Main Cropping Seasons at Bekoji and Asasa Areas**

Treatment	Grain yield (kg/ha)	Above ground biomass (kg/ha)	Harvest index (%)	Plant height (cm)
Location				
Bekoji	2881	6688	42.3	102.6
Asasa	2845	6879	40.7	106.4
LSD	ns	ns	ns	ns
Rotational crops				
Ethi. Mustard	1852	5433	33.2	175.5a
Faba bean	2339	5221	44.8	91.0b
Wheat	3894	8148	48.2	91.5b
Wheat	4052	8951	45.3	91.5b
Sweet lupine	2179	6568	36.1	73.0b
LSD	ns	ns	ns	41.7
CV (%)	22.38	33.26	16.21	14.37

Means followed by the same letter in a column are not significantly different at  $P < 0.05$ .

Although non-significant, the third year Bekoji and Asasa combined analysis of variance revealed that the highest wheat grain yield (4197kg/ha) was obtained at sweet lupine-wheat-wheat followed by wheat-faba bean-wheat (4003kg/ha). Similarly, also reported that in the most diverse crop rotation the average spring wheat yield was on average 21% higher than the yield in the wheat monoculture. Similarly, above ground biomass, harvest index, thousand kernel weight, hectoliter weight and number of seeds per kernel were also non-significant (table 4). However, plant height was significantly ( $P < 0.05$ ) affected by rotational crops effect. Tallest plant height which of wheat is 105.0cm was recoded from wheat –Ethioian mustard-wheat treatment followed by wheat- faba bean – wheat. Despite the result was non-significant, the three years analyzed data of wheat-faba bean-wheat grain yield (2946-2339-4003 kg/ha), sweet lupine-wheat-wheat (3613-3894-4197 kg/ha) followed by wheat-wheat- wheat (3737-4052-3568) resulted in comparatively good yield. Actually, nitosols of Bekoji is known for its acidity and therefore looking for alternative and multipurpose rotational crop such as sweet lupine is advantageous for its nutritional, feed and food for resource poor farmers.

**Table 5: Effect of Rotational Crops on Yield and Yield Components of Bread Wheat based Rotations Combined Over Locations in 2019 Main Cropping Seasons at Bekoji and Asasa areas**

Treatment	Grain yield (kg/ha)	Above ground biomass (kg/ha)	Harvest index (%)	Thousand kernel weight (g)	Hectoliter weight (kghl-1 )	Plant height (cm)	# Seed/ spike
Location							
Bekoji	3009b	7723b	39.2	37.5a	75.8	101.6a	47.4
Asasa	4353a	13010a	33.4	33.4b	77.0	97.6b	48.6
LSD	1338.8	3250.5	ns	2.741	ns	2.32	ns
Rotational crops							
Wheat	3525	10355	35.5	34.9	76.0	105.0a	47.0
Wheat	4003	11518	35.8	35.9	77.0	98.5b	49.0
Wheat	4197	11274	36.9	37.4	77.5	99.0b	41.0
Wheat	3568	10276	35.7	34.4	76.5	98.5b	49.0
Wheat	3113	8411	37.6	34.7	75.0	97.0b	54.0
LSD	Ns	ns	ns	ns	ns	3.67	ns
CV (%)	20.71	17.86	12.81	4.41	1.52	1.33	9.68

Means followed by the same letter in a column are not significantly different at  $P < 0.05$ .

### Conclusion and Recommendations

These leguminous crops have improved physico-chemical properties of soil. Plant nutrients of soil on which legumes were grown were increased. This improvement of soil properties by leguminous crops has resulted in higher yield of wheat than plots on which wheat was grown after wheat. The third year data of this experiment showed that highest wheat grain yield (4197kg/ha) was obtained at sweet lupine-wheat-wheat followed by wheat-faba bean-wheat (4003kg/ha). Crop rotation is not only for temporary income increment, but also very important for sustainable agriculture. From this study, sweet lupine-wheat-wheat followed by wheat-faba bean-wheat with proper agronomic packages could be forwarded as a temporary recommendation in Asasa, Bokoji and Kulumsa areas and in areas with similar agro ecologies.

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