SHORT RAIN SEASON FALLOW: WINDOW OF OPPORTUNITY FOR INTEGRATING IMPROVED FALLOW LEGUMES INTO THE FARMING SYSTEM OF MOLO DISTRICT, KENYA

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ABSTRACT

The rainfall pattern in Molo district, situated in the central Rift Valley province of Kenya, is bimodal in nature with long (4-5 months) and short (2-3 months) rain seasons being experienced annually. The short rains are often unutilized by farmers partly due to the acidic nature of the soils that is a hindrance to growth of short maturing crops such as legumes. It was thus hypothesized that planting improved fallow legumes; cowpea (CP) and crotalaria (CR) with application of soil amendments; lime (L), rock phosphate (RP), and farm yard manure (FYM) in the short rain season (SRS) would better utilize the SRS fallow. CP and CR were planted in the SRS of 2005 and 2006 with (CP_{L+RP}, CR_{L+RP} and $CR_{L+RP+FYM}$) and without (CP_0 and CR_0) application of soil amendments. The experiment was laid out in a randomized complete block design. At CP maturity and CR flowering, the aboveground biomass was incorporated in the soil except in the $CR_{L+RP+FYM}$ treatment where the aboveground biomass was removed and FYM added instead. A weed fallow (WF) was included as a control. Soil pH, available N and P were measured at 0, 15, 90 and 120 days after sowing (DAS) of legumes. Biological nitrogen fixation was measured at late pod fill stage of CP and flowering stage of CR, respectively. The aboveground biomass, grain yield (CP), N and P contents were measured at CP maturity and CR flowering, respectively. The measured soil pH (H_2O), at the end of 2006 SRS, had significantly increased from the initial value of 4.94 to 6.0, 6.2 and 6.1 in the treatments; CP_{L+RP}, CR $_{L+RP}$ and $CR_{L+,RP+FYM}$, respectively. CR fixed significantly ($P<0.05$) higher amounts of N_2 (127 - 158 kg ha^{-1}) than CP (37 – 56 kg ha^{-1}) in both seasons with significantly higher amounts fixed in CR_{L+RP} treatment. There were marked fluctuations in soil available N and P across sampling periods with treatments; $CR_{L+RP+FYM}$, CR_{L+RP} (N and P), CR_0 (N) and CP_{L+RP} (P) recording significantly higher levels of N at 120 DAS. CP grain yield was significantly higher in treatment; CP_{L+RP} (0.6 and 0.68 t ha^{-1}) than in CP_0 (0.20 and 0.17 t ha^{-1}) for both seasons. Aboveground biomass (t ha^{-1}) across treatments and seasons increased in the order WF, CR and CP. The plant N and P content (kg ha^{-1}) were significantly higher in CP_{L+RP} and $CR_{L+RP+FYM}$ for both seasons. There were no significant differences in the measured parameters between CR_{L+RP} and $CR_{L+RP+FYM.}$ CR residue can therefore be incorporated directly into soil or fed to livestock and recycled back to the cropland as FYM. Planting improved fallow legumes, with application of soil amendments, better utilized the SRS fallow and is a sustainable approach to ameliorating soil pH and enhancing soil available N and P to the benefit of the subsequent LRS crop. The legumes would further provide a cheaper source of protein in the farmers' diet (CP grains) besides being sold to fetch income and used as livestock feed (CR).

Keywords: short rain season crops, crotalaria, cowpea, rock phosphate, lime, farmyard manure.

INTRODUCTION

The annual rainfall received in Molo district, situated in the central Rift Valley province of Kenya, has a bimodal pattern in distribution with distinct long (LRS) and short rain season (SRS). During the long rains, maize is cultivated as a monocrop or in some cases intercropped with common beans. The short rains are however unutilized thus leaving the land under a 3 to 4 month weed fallow. This period is too short to allow for natural soil fertility regeneration but long enough to allow for the growth of improved fallow legumes. Improved fallow legumes consist of deliberately planted legume species with the primary purpose of fixing N as part of a crop-fallow rotation (Mapfumo *et al*., 2005). Legumes have been reported to have substantial residual benefits for successive crops. It is probable that if farmers were to utilize the SRS fallow by planting improved fallow legumes, the soil nutrient status, especially N, would be enhanced and concomitantly ensures increased farm productivity.

There is however one setback, and key reason for leaving the land fallow, to the successful integration of legume into the farming system of Molo. The soils are inherently acidic with pH (H_2O) below 5.0 (Lelei, 1999 and Onwonga *et al*., 2008). In this pH range, Al concentration increases and becomes easily soluble and impairs legume growth. Most leguminous plants require a neutral or slightly acidic soil for growth, especially when they depend on symbiotic N_2 fixation (Bordeleau and Prevost, 1994). Low soil pH is also associated with increased Mn toxicity and reduced, Mo, P and Ca supply (Lukin and Epplin, 2003). Mo and P are necessary for nodule initiation and metabolism, respectively whereas Ca is important in the initial attachment of rhizobial cells to the root hair tips. Good nodulation and N_2 fixation rates occur above pH 5.3 (Daniel and Roger, 2002).

The liming of acid soil has been suggested as the most efficient practice available to attain and maintain a suitable pH for the growth of a variety of crops (Coventry *et al*. 1997). Using manures on the other hand alleviates aluminum toxicity and improves the availability of nutrients such as P, particularly in soils with a high P fixation (Kimani *et al*., 2001). Manure also supplies essential elements such as Mg, and trace elements which may not be available in commonly used inorganic fertilizers (Kimani *et al*., 2001). Furthermore application of high doses of plant available P is essential for sustaining and increasing crop production. Nonetheless, the use of imported phosphate by the resource poor farmers is impractical due to high prices. However, direct application of local phosphate rock can reduce dependency on expensive, imported processed fertilizers (Sikora 2002). In P deficient and acidic soils, Minjingu rock phosphate (MRP) has proven to be as effective as imported water-soluble triple super phosphate as well as being more profitable to farmers (Sanchez *et al*., 2000). The use of lime, Minjingu Rock Phosphate (MRP) and manure to address soil acid infertility is however not common in this region partly due to lack of awareness and empirical data to support the need for the same.

It was thus hypothesized that planting improved fallow legumes; cowpea (CP) and crotalaria (CR), with application of soil amendments; lime (L), rock phosphate (RP), and farm yard manure (FYM) would better utilize the SRS fallow with resultant amelioration of soil pH and increased soil available N and P.

MATERIALS AND METHODS

Site description

The experiment was carried out on farmers fields in Molo district (0°12´S, 35°41´E, 2500 m asl) situated in the central Rift Valley Highlands of Kenya, during the SRS of 2005 and 2006. The district is agroecologically representative of Kenya's high agricultural potential areas as measured by rainfall and soil type (Jaetzold and Schmidt, 1983). The traditional agriculture of the area is based on a mixed crop-livestock production and is mainly rain fed (Jaetzold and Schmidt, 1983 and Omamo *et al*., 2002). The main crops grown in the LRS include maize, potatoes, beans, carrots, tomatoes and limited temperate fruits. Maize, often intercropped with beans, dominates the cropping pattern. Cash crops (e.g. pyrethrum and various horticultural commodities in relatively small scale) are also grown (Jaetzold & Schmidt, 1983; Obare *et al*., 2003). The rainfall distribution in Molo is bimodal in nature with the long rains occurring from March to July/August and the short rains from September/October to December with peaks in April and November. The soils are acidic, well drained, deep, dark reddish brown with a mollic A horizon and are classified as mollic Andosols (FAO-UNESCO, 1990). The measured initial soil characteristics at 0 - 20 cm depth were; total N (0.17%) available P (3.30 mg kg^{-1}), organic C (1.56%), C: N ratio (9.2), pH (H_2O, 4.94) and exchangeable Al (1.5 cmol kg^{-1}).

Treatments and experimental design

Treatments and experimental design: CP and CR were planted in the SRS of 2005 and 2006 with (CP_{L+RP}, CR_{L+RP} and $CR_{L+RP+FYM}$) and without (CP_0 and CR_0) application of soil amendments. A weed fallow (WF) was included as the control. The experiment was laid out in a randomized complete block design in plots measuring 3.75m x 4.8 m and replicated three times.

Agronomic practices

Land was prepared manually using hand hoes followed by secondary cultivation which involved raking and leveling. L (3 t ha^{-1}) and RP (290 kg ha^{-1}) were broadcasted two months prior to planting and a week to planting of the improved fallow legumes, respectively. FYM, at a rate of 5 t ha^{-1}, was placed in the planting holes (banding), a week to planting of the improved fallow legumes. FYM was used in the treatment $CR_{(L+RP+FYM)}$ to allow for the feeding of the CR to livestock and recycled back to crop field as manure.

CR and CP were planted at a spacing of 75 cm x 30 cm in pure stands at the start of the SRS of 2005 and 2006. Two seeds were planted per hole and thinned to one plant 30 days after sowing (DAS). For the estimation of N_2 fixation, barley was sown at the same time as the improved fallow legumes at the rate of 100 kg ha^{-1} in furrows of about 3 cm depth at an inter-row distance of 20 cm. At CP maturity and CR flowering, the aboveground biomass was incorporated in the soil except in the $CR_{L+RP+FYM}$ treatment where the aboveground biomass was removed and FYM added instead.

In the LRS, either maize or maize/bean intercrop, depending on farmers' preference, were planted on the experimental plots by the respective farmers under the guidance of the researcher. The experimental plots were farmer managed and crop performance; growth and yields were recorded on simple record sheets designed for the farmers. The idea was to credit any observed changes in maize performance to planting of the improved fallow legumes with application of soil amendments in the SRS and in addition increase the chances of integrating legumes into the maize based cropping system.

Soil sampling and analysis

Initial soil properties were characterized by sampling prior to application of soil amendments and actual field trials. Thereafter, samples were collected at 15, 90 and 120 DAS of the improved fallow legumes in the SRS of 2005 and 2006. At each sampling time, four sub samples were obtained from the top soil (0-20 cm depth) between the plants within a row in every plot, using a 5 cm diameter soil auger. The samples were kept in polythene bags in a portable cool box to avoid loss of water and analyzed for available soil N, P and pH (measured in water in a soil-to-water ratio of 1:2.5) according to the methods described by Okalebo *et al*. (2002).

Plant sampling and analysis

CP and CR aboveground biomass determination:

Aboveground biomass of CP and CR and fallow weeds was determined at harvest and cutting, respectively from the two centre rows. Aboveground biomass of weeds was taken using a 1m^2 quadrant. Fresh weights were immediately determined in the field using a weighing balance. Sub samples were collected, placed in paper bags and taken to the laboratory where they were air dried (60-70^{o}C) for dry weight determination. All plant materials were ground to pass though a 1.0 mm mesh screen and analyzed for N and P content using the methods described by Okalebo *et al*. (2002).

Cowpea grain yield determination: Cowpea dry pods were harvested after drying in the field by hand from the two centre rows of each plot. Grain yield was adjusted to 11% moisture contents.

Determination of N_2 fixation

The amounts of N_2 fixed by the legumes were determined at the late pod fill stage of CP and at flowering stage of CR. The extended difference method [the fourth extension, Hauser (1987)] was used. The method assumes that the uptake of soil derived N is the same in the legume and reference crop. Barley, a crop with similar N uptake characteristics as the legumes was chosen (Jensen, 1986; Reining, 2006). The biological nitrogen fixation (BNF) by legumes was calculated using the formula:

BNF (kg ha^{-1})
$= (\text{shoot } N_{leg} + \text{root } N_{leg}) - (\text{shoot } N_{ref} + \text{root } N_{ref}) + (N_{in} \text{ in soil}_{leg} - N_{in} \text{ in soil}_{ref})$

Where
leg = legume; ref = reference crop; in = mineral N

Statistical analysis

The data obtained was subjected to analysis of variance (ANOVA) using SPSS (SPSS Incorporated, 1999) software. The analysis was appropriate to a randomized complete block design. Tukey tests were used for comparison of means.

RESULTS

Soil pH

Soil pH increased from the initial value of 4.94 in 2005 SRS to 6.0, 6.16 and 6.10 in the treatments CP$_{(L+RP)}$, CR$_{(L+RP)}$, and CR$_{(L+RP+FYM)}$ at the end of the 2006 SRS (Table-1). The rise in soil pH was due to the application of soil amendments which neutralized the soil acidity. The neutralization of Al^{3+} and H^+ ions through lime application resulted in pH increase. RP with its high content of carbonates also had a liming effect (Weil, 2000) and hence had the same effect as lime. According to Weil (2000), when lime is added to soil, it reacts with water leading to the production of OH ions which react with Al^{3+} and H^+ ions in the acid soil to form Al $(OH)_3$ and H_20 (Hao *et al*., 2002). Besides, FYM on decomposition produces organic acids which may have suppressed the Al activity in the soil through chelation (Haynes and Mokolobate, 2001). The raised soil pH, as a result of the application of soil amendments, falls within the pH range (5.6-7.5) that is suitable for the growth of most crop species (Kanyanjua *et al*., 2002).

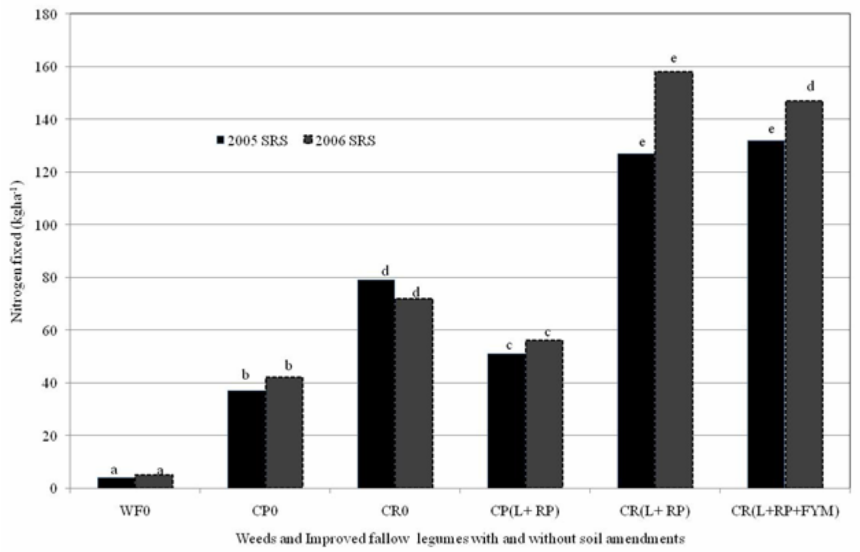
Table-1. Soil pH changes during the experimental period (means of 3 observations).

Treatment	Days after application of Lime							
	2005 SRS				2006 SRS			
	0	15	90	120	0	15	90	120
WF	4.94(0.02)	4.95^a(0.30)	4.95^a(0.02)	4.86^a(0.02)	4.81^a(0.01)	4.84^a(0.03)	4.79^a(0.01)	4.80^b(0.08)
CP$_0$	4.94(0.02)	4.93^a(0.02)	4.94^a(0.02)	4.91^a(0.04)	4.87^a(0.03)	4.82^a(0.02)	4.89^a(0.03)	4.90^a(0.05)
CR$_0$	4.94(0.02)	4.94^a(0.02)	4.95^a(0.03)	5.01^a(0.01)	4.97^a(0.02)	4.92^a(0.04)	4.98^a(0.02)	5.12^a(0.11)
CP$_{(L+RP)}$	4.94(0.02)	4.97^a(0.01)	5.40^b(0.16)	5.61^c(0.10)	5.76^c(0.04)	5.89^c(0.02)	5.92^b(0.07)	6.00^c(0.05)
CR$_{(L+RP)}$	4.94(0.02)	5.02^a(0.12)	5.46^b(0.04)	5.58^c(0.01)	5.78^c(0.12)	5.86^c(0.09)	5.99^b(0.02)	6.16^c(0.06)
CR$_{(L+RP+FYM)}$	4.94(0.02)	4.94^a(0.03)	5.01^a(0.13)	5.21^b(0.12)	5.56^b(0.15)	5.79^b(0.11)	5.86^b(0.21)	6.10^c(0.14)

Means in a column followed by the same letter are not significantly different at $P < 0.05$ using the Tukey mean separation procedure. Standard deviations in parenthesis

N_2 fixation

CR, with or without application of soil amendments, fixed significantly higher amounts of N_2 than CP and WF in the SRS of 2005 and 2006 (Figure-1). Significantly higher amounts of N were fixed in the treatments CR$_{(L+RP+FYM)}$ and CR$_{(L+RP)}$ than CR$_0$ for both seasons.



Means of nitrogen fixed for each treatment and cropping system followed by the same letter are not significantly different at $p < 0.05$ according to Tukey mean separation procedure

Figure-1. Nitrogen fixed (kg ha^{-1}) by weeds, cowpea and crotalaria in 2005 and 2006 SRS (means of 3 observations).

The significantly ($P<0.05$) higher amounts of N fixed by CR than CP may be credited to better adaptation of CR to the prevailing environmental conditions and its better genetic potential (Fischler *et al*., 1999). This is in addition to the improved soil conditions as a result of the application of the soil amendments that neutralized soil acidity. This led to the reduction of Al ions (Hao *et al*., 2002) with resultant increased soil pH (pH<5.5). Al replaces other polyvalent cations (Ca^{2+}, Mg^{2+}) on the cation exchange sites and simultaneously acts as a strong adsorber of phosphates (Mokwunye *et al*., 1996, Delgado and Torrent, 2000). In legumes, nodulation is adversely affected by a combination of high Al and/or Mn and low Ca concentrations (Giller, 2001). Low P availability also has a negative effect on legume nodulation (Kidd and Proctor, 2001). The amount of N_2 fixed by CR in this study falls within the range of the potential legume nitrogen fixing capacity (50-450 kg ha^{-1}) under tropical conditions as reported elsewhere in literature (Unkovich and Pate, 2000; Giller, 2001; Unkovich and Pate, 2000; Smithson and Giller, 2002), an indication of the effectiveness of the soil amendments applied. The higher BNF in the 2006 SRS than the 2005 SRS would be due to improved soil conditions and subsequent supply of nutrients such as Mo, P and Ca that are key in N fixation, as a result of sufficient soil reaction with the applied amendments.

Soil available N

The initial soil available N content prior to legume sowing, in the SRS of 2005 was 18 kg ha^{-1} and thereafter was characterized by distinct fluctuations (Figure-2). Significantly higher amounts of N were found in $CR_{(L+RP)}$ and $CR_{(L+RP+FYM)}$ treatments at 15 DAS in the 2005 SRS. However at 90 DAS significantly higher ($P<0.05$) amounts in soil available N were found in CP_0 and $CP_{(L+RP)}$ treatments with significantly higher amounts found in the latter (Figure-2).

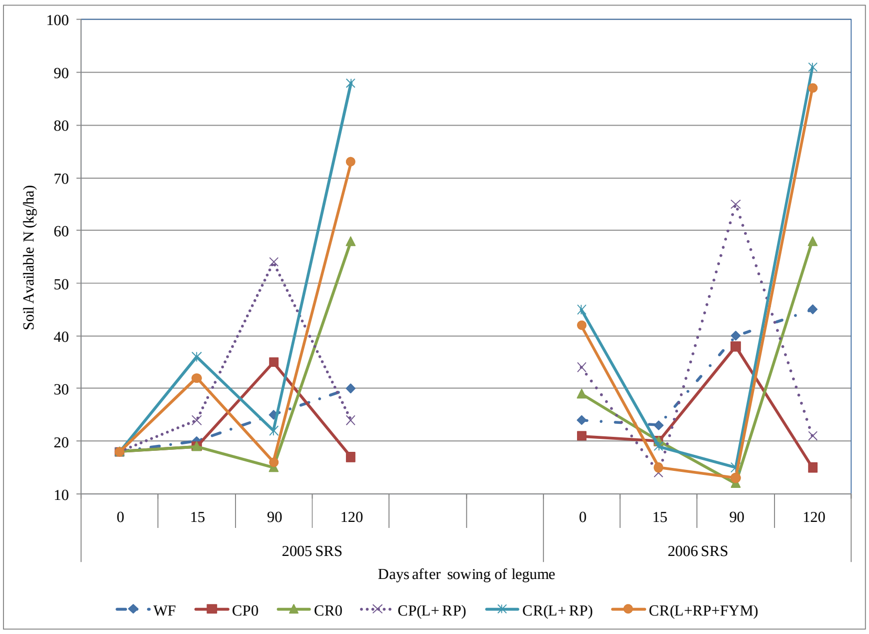


Figure-2. Soil available N (kg ha^{-1}) during legume growth.

At 120 DAS significantly higher amounts of soil available N were found in CR$_0$, CR $_{(L+\ RP)}$ and CR $_{(L+RP+FYM)}$ treatments (Figure-2). In the 2006 SRS, significantly higher amounts of soil available N were recorded at planting and 15 DAS in CR $_{(L+\ RP)}$ and CR $_{(L+RP+FYM)}$ treatments. At 90 DAS and 120 DAS the trend was similar to the preceding 2005 SRS. In the WF, gradual increase in soil available N for both seasons was observed (Figure-2).

The significantly high levels of soil available N at 15 and 120 DAS in CR $_{(L+\ RP)}$ and CR $_{(L+RP+FYM)}$ treatments is attributable to the beneficial effect of lime and RP application on nitrification. Liming of acid soils led to increased soil pH thus creating favourable conditions for soil organic matter decomposition and hence enhanced N mineralization (Rahn *et al*., 2003). Soil pH is recognized as an important regulator of microbial activity which is key in solubilization of organic P compounds, N mineralization and organic matter decomposition (Delgado and Torrent, 2000; Giller, 2001).

The high levels of soil available N observed at 90 DAS (mid flowering of cowpea) in CP$_{(L+\ RP)}$ and CP$_0$ treatments in the 2005 and 2006 SRS is as a result of BNF by CP. Whereas the low soil available N found in CR $_{(L+\ RP)}$ and CR $_{(L+RP+FYM)}$ at 90 DAS is attributed to N uptake by CR. It was still at its vegetative stage and thus used the N present in soil for its growth and development. However, at 120 DAS significantly higher levels of soil available N were obtained probably due to improved soil conditions with application of soil amendments and thus enhanced mineralization of soil organic matter and senescing roots and leaves of CR.

The higher amounts of soil available N found in treatments CR$_{L+RP}$ and CR$_{L+RP+FYM}$ than in the WF and CP$_0$ at 120 DAS in 2005 and at 90 and 120 DAS in 2006 are due to enhanced soil conditions with application of the soil amendments. The lower amounts obtained in the CP$_0$ and WF fallow treatments may be attributed to the, continuous uptake by the roots during cowpea growth and the inferior BNF capacity of CP compared to CR. This observation was also reported by Fening and Danso (2005) who also found that CP drew a high proportion of its N from the soil pool during its growth.

Soil available P

The initial soil available P content prior to legume sowing, in 2005 SRS, was 3.3 mg kg^{-1} and thereafter was characterized by marked fluctuations with progression of legume growth. Significantly higher amounts of soil available P were found in the treatments CR $_{(L+\ RP)}$ and CR $_{(L+RP+FYM)}$ followed by CP $_{(L+\ RP)}$ treatment at 15, 90 and 120 DAS for both the SRS of 2005 and 2006 (Figure-3).

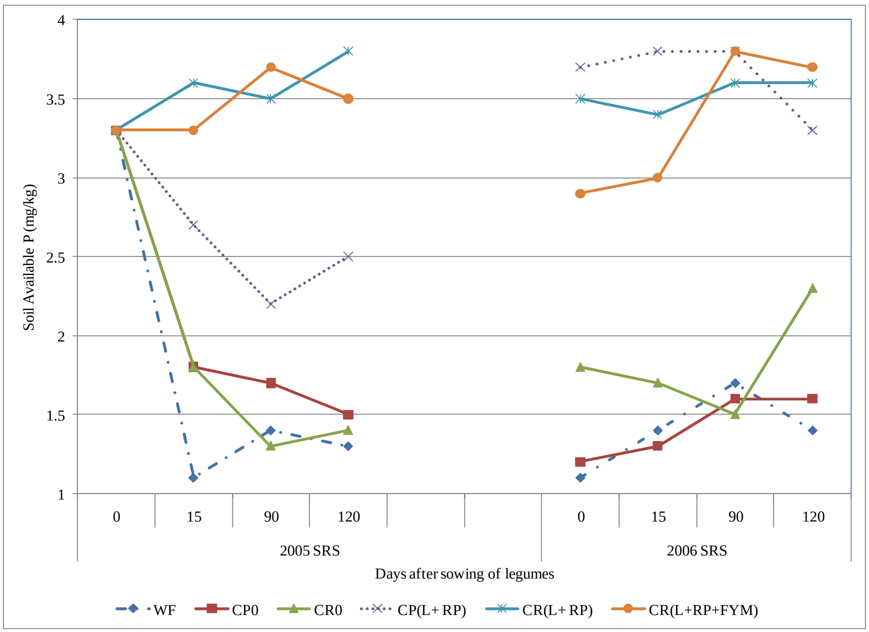


Figure-3. Soil available P (mg kg^{-1}) during legume growth.

The higher amounts of soil available P observed in the treatments CR $_{(L+RP)}$, CR $_{(L+RP+FYM}$ and CR $_{(L+RP,}$ across sampling times and growing seasons, was due to the application of the respective amendments. P deficiency observed in acid soils is often associated with high P fixation and severe soil acidity (Mokwunye *et al*., 1996). Liming reduces Al toxicity, (Hao *et al*., 2002) and increases extractable P, Ca and Mg (Chang and Sung, 2004). RP similarly supplied P and its solubility was enhanced by CP and CR legume exudates. According to Vanlauwe (2003) the high proton excretion of legume roots, typically for symbiotically living leguminous species (Mengel, 1994), contributed to the dissolution of rock phosphate. Organic molecules, provided by the FYM, enhance P availability by binding exchangeable and hydroxyl-Al, the key fixers of P in acid soils and they are also key in dissolving phosphate rock (Haynes and Mokolobate, 2001). This is in addition to the supply of nutrients to plants and the carbon containing compounds providing substrates for soil animals and micro-organisms (Latham, 1997; Thakare and Gupta, 2003).

Little fluctuation in soil available P with progression of legume growth was observed in WF, CP_0 and CR_0. This can be attributed to P fixation in the acid soil. Phosphorus forms insoluble compounds with Al^{3+} at low pH (Tisdale *et al*., 1990; Hao *et al*., 2002).

Crotalaria, cowpea and weed aboveground biomass and their N and P contents

Aboveground biomass production: The aboveground biomass of WF, CP and CR were significantly higher during the SRS of 2006 than 2005. The WF, consisting mainly of the species Amarathus hybridus, Comelina beghalensis, Digitaria scalarum, Gallinsonga parviflora and Peninisetum clandestinum, had significantly higher aboveground biomass, followed by CR and CP in that order (Table-2).

Table-2. Aboveground biomass and nutrient contents of CP, CR and WF (means of 3 observations).

Treatment	**Plant**	**Aboveground biomass** (t ha^{-1})		**Nutrient content** (kg ha^{-1}) **in aboveground biomass**			
				N		**P**	
		2005	2006	2005	2006	2005	2006
WF	weeds	4.97^{b}(0.02)	5.81^{a}(0.10)	56.72^{b}(2.96	72.76^{c}(2.23)	5.21^{c}(0.28)	5.44^{bc}(0.17)
CP$_0$	cowpea	1.10^{a}(0.10)	2.37^{c}(0.10)	20.79^{a}(1.64)	30.55^{a}(1.98)	1.85^{a}(0.15)	2.85^{a}(0.22)
CR$_0$	crotalaria	1.92^{e} (0.06)	2.86^{d}(0.05)	78.22^{c}(4.05)	82.42^{c} (3.28)	6.23^{c}(0.64)	6.37^{c}(2.21)
CP$_{(L+ RP)}$	cowpea	1.68^{d}(0.04)	2.79^{c}(0.05)	27.99^{a}(1.73)	47.42^{b}(1.58)	3.49^{b}(0.21)	3.33^{a}(1.01)
CR$_{(L+ RP)}$	crotalaria	2.49^{f}(0.03)	3.40^{e}(0.05)	91.71^{e}(3.76)	108.90^{d}(3.62)	7.74^{d}(0.07	6.81^{c}(0.22)
CR$_{(L+RP, FYM)}$	crotalaria	2.30^{f}(0.04)	3.88^{f}(0.36)	72.18^{d}(4.36)	132.44^{d}(11.21)	6.22^{c}(0.79	7.85^{c}(0.64)

Means in a column followed by the same letter are not significantly different at $P<0.05$ according to the Tukey mean separation procedure. Standard deviations in parenthesis.

The higher aboveground biomass of the WF may be attributed to rapid growth and establishment in comparison to the improved fallow legume species. Higher aboveground biomass production in treatments CP$_{(L+ RP)}$, CR$_{(L+ RP)}$ and CR$_{(L+ RP)}$ during the SRS of 2006 was as a result of the improved soil productivity due to amelioration of soil pH by the soil amendments. This is in addition to the residual effect and slow nutrient release by FYM (Haynes and Mokolobate, 2001).

Nutrient content: The N and P content was significantly higher in the aboveground biomass of CR$_0$, CR$_{(L+ RP),}$ and CR$_{(L+RP, FYM)}$ treatments than WF for both seasons with a marked increase in the SRS of 2006 (Table-2). The WF had significantly (P<0.05) higher N and P contents than CP (CP$_0$ and CP $_{(L+ RP)}$).

The higher nutrient content in CR$_0$ and WF than CP$_0$ and CP $_{(L+ RP),}$ was because of the higher aboveground biomass produced by CR relative to CP (Table-2) which translated to high plant tissue N and P content. Gathumbi *et al*. (2005) studying short term fallows reported a linear positive relationship between aboveground biomass production with plant N content for all legume species. Improved CR fallows recorded the greatest total N yield and they attributed the same to fast establishment and higher total aboveground biomass production. The significantly high aboveground biomass production by CR is attributable to enhanced soil conditions upon application of the soil amendments coupled with its better adaptation (Fischler *et al*., 1999).

Cowpea and maize grain

Cowpea grain yield (t ha^{-1}) was significantly higher in treatment CP $_{(L+ RP)}$ (0.60) than CP$_0$ (0.20) in the 2005 SRS. A similar trend was observed in the 2006 SRS, where grain yield was significantly higher in CP $_{(L+ RP)}$ (0.68) than CP$_0$ (0.17). The higher grain yields in CP$_{(L+ RP)}$ is attributable to the improved soil conditions upon application of soil amendments with resultant increased soil available N, P and Ca and consequently enhanced legume performance. Liming acid soils improves yields because of the rise in soil pH which is conducive for plant growth and microbial organic matter decomposition, and mineralization of nutrients (N, P and S). The mineralized nutrients are then made available for crop uptake, thus contributing to yield increase (Kanyanjua *et al*., 2002). From the respective farmers' records on maize grain yield, the yield increases above WF, averaged across the two seasons were; 22, 25, 31, 36 and 44% for CP$_{0,}$ CR$_{0,}$ CP $_{(L+ RP),}$ CR $_{(L+ RP),}$ CR $_{(L+RP+FYM)}$. This is attributable to the BNF by the legumes (Figure-1) and enhanced soil conditions with the application of soil amendments that resulted in increased soil pH (Table-1) and soil available N and P (Figures 2 and 3).

CONCLUSIONS

The integration of improved fallow legumes, alongside the application of the soil amendments, into the maize based cropping system better utilized the SRS fallow and resulted in a win-win situation through; amelioration of soil pH and enhanced soil available N and P. Besides, a second crop with potential of; BNF, provision of supplementary proteins to farmers' diet (CP) and livestock feed (CR) could be harvested during the year.

The weed species produced high aboveground biomass but of low quality, conversely CR and CP produced lower aboveground biomass but of high quality in terms of tissue N and P concentration. The CR can be incorporated directly in soil or fed to livestock and recycled back to cropland as FYM. Lime reaction in soil released fixed P resulting to increased soil available N and P levels. RP, equally had the same effect, and is recommended for use as an affordable source of P in farming systems that integrate legumes.

The increase in N and P undoubtedly contributed to the improved performance of the subsequent maize crop in the long rain season. It is evident from this study, therefore, that the SRS fallow, with application of soil amendments, could provide a window of opportunity for integrating improved fallow legumes into the maize based cropping system of Molo district, Kenya and other regions in the tropics and sub-tropics with similar agro-ecological conditions.

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