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African Journal of Agricultural Research

*Full Length Research Paper*

# Effect of fertilizers amendment on yield and yield components of wheat (*Triticum aestivum* L.) on acidic soil of Tsegede Highland, Northern Ethiopia

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**A field experiment was carried out during 2012/2013 on acidic soil of Tsegede highlands, Northern Ethiopia to evaluate wheat crop response to different Fertilizers and Liming with four treatments: (1) (No fertilizer), (2) 64 kg/ha Nitrogen+ 150 kg/ha Minjingu organic hyper phosphate fertilizer, (3) 64 kg/ha Nitrogen and 20 kg/ha Phosphorus, and (4) 64 kg/ha Nitrogen and 20 kg/ha Phosphorus + 4.17 t/ha lime were arranged in Randomized Complete Block Design (RCBD) deign with three replications. Soil samples were collected before planting and analyzed for selected physicochemical properties, which revealed that textural class was sandy loam and the pH, Exchangeable aluminum and Exchangeable Acid as very strong acid and toxic for plant growth. The total percentage of organic matter, Nitrogen and Cation Exchange capacity (CEC) were as high; while very low in available phosphorus. Results indicated soil that received 64 kg/ha Nitrogen from urea+150 kg/ha Minjingu organic hyper phosphate, 64 kg/ha Nitrogen and 20 Phosphorus and 64 kg/ha Nitrogen and 20 kg/ha Phosphorus + 4.17 t/ha lime gave additional grain yield increment by about 191, 211 and 413% over the control, respectively. While the straw yield improved by 226, 248 and 422% respectively. The highest yield was recorded on soils with 64 kg/ha Nitrogen and 20 kg/ha Phosphorus along with lime followed by the 64 kg/ha Nitrogen and 20 kg/ha Phosphorus, and soil with application of 64 kg/ha Nitrogen from urea+150 kg/ha Minjingu organic hyper phosphate. The recorded plant height was significantly affected only at 64 kg/ha Nitrogen and 20 kg/ha Phosphorus + 4.17 t/ha lime (21.2%) over the control. Hence uncontrolled land encroachment in the low land areas can minimize to make these farmlands productive. The rate of these fertilizers and marginal rate of return was not studied.**

**Key words:** HAR-604, lime, Minjingu organic hyper phosphate, nitrogen, phosphorus.

## INTRODUCTION

Wheat is an important crop that is grown on more acres globally than any other and provides a major share of the nutritional requirements for the growing world population (Shapiro, 2009). It is cultivated in Ethiopia on about 1.51 million hectares and delivers about 3.3 million tons of grain, which makes Ethiopia the largest wheat producer

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in sub Saharan Africa (CSA, 2013). However, Soil chemical degradation such as (soil acidity, salinity and sodicity, low levels of fertilizers), pesticides and improved seeds, moisture stress, are some of the major crop production constraints in Ethiopia (Taffesse et al., 2011). Acid soil infertility is a major limitation to crop production on highly weathered and leached soils in the tropical and temperate regions of the world (Uexküll and Mutert, 1995), particularly in tsegede highlands (Kidanemariam et al., 2013). In addition to this, the fertilizer use focus was only on N and P fertilizers in the form of di-ammonium phosphate (DAP) and urea for all cultivated crops in all agro ecologies and on all soil types for the last several years. Such unbalanced application of plant nutrients has aggravated depletion of other important nutrient elements in soils. Among the key strategies that were identified to help increase agricultural production and productivity in the Growth and Transformation Program one (GTP1) period was the soil fertility mapping of the country's agricultural lands. In Tsegede highlands four soil nutrients {Nitrogen (N), phosphorus (P), Sulfur (S) and Boron (B)} are found to be deficient in the soils (MOA and ATA, 2014), and characterized by low pH level and high Exchangeable Aluminum (Kidanemariam et al., 2013) and (MOA and ATA, 2014). About 30% of the highly weathered soils of Ethiopia have been reported to be acidic (Mamo et al., 1988) and more than 81% of the Tsegede highlands are under strong acid (Kidanemariam et al., 2013). The need to transform agricultural sector with respect to soil fertility requires application of proper amounts of blended fertilizers and soil amendments for different crops. Besides, the importance of these nutrients in yield enhancement and quality improvement is utmost a great concern. This recalls that evaluation of different fertilizers and their amendment for optimum crop production. Fertilizers amendment has this all primary, secondary, micronutrients, and soil reclamation. There have been few or no studies on newly introduced fertilizers formulated like Minjingu organic hyper phosphate (28-30%$P_2O_5$) with liming in the country particularly in the acid soil of Tsgegede. Thus, it is essential to evaluate these fertilizers and liming effect on the acidic soil of tsegede district.

## Objective

To evaluate different fertilizers amendment effect on yield and yield components bread wheat grown on the acid soils of the area.

## MATERIALS AND METHODS

### Area description

The experiment was conducted on very strong acid soil of the high lands of Tsegede District which is located in the western Zone of Tigray Region, northern Ethiopia, located at 13° 14′ 21″ and 13° 44′ 46″ north and 36° 27′ 44″ and 37° 45′ 05″ longitudes with an altitude of 1053 to 2889 m above sea level. The mean annual rainfall of the area is about 2316 mm that usually starts at about the end of March and ends in early November with the peak in August. The mean annual temperature of the area is 13.2°C and ranges from 7.8 to 18.6°C. The study site was at Endasslassie kebelle, with area coverage of 84.7 $km^2$. It consists of high and rugged mountains, flat topped plateau, deep gorges and rolling plains. The dominant soil types in the Tsegede highlands are mainly Humic Cambisols (Kidanemariam et al., 2013). Wheat (Triticum spp.), Barley (*Hordeum vulgare*), Teff (*Eragrostis tef*), fingermillet (*Eleusine coracana*), Faba bean (*Vicia faba*), Field pea (*Pisum sativum*), Noog (*Guizotia abyssinica*), and Linseed (*Linum usitatissimum*) are Crops which are grown mostly in the highlands of the District.

### Site selection, soil sampling and laboratory analysis

This was conducted across two acid affected locations each has three replication. A composite soil sample was taken by inserting the auger up to a depth of 20 cm. All the subsample of a single composite sample were collected and taken using quartering method with the necessary label on it. It was air-dried and sieves to pass through 2mm diameter mesh sieve except for soil organic carbon (OC) and total N analysis that passed through 0.5 mm sieve.

Laboratory analysis was made for Texture, pH, Organic carbon, Total Nitrogen, Available Phosphorus, Exchangeable acid, Exchangeable Aluminum (Al) and Cation Exchange Capacity (CEC) following their respective standard procedures. Particle size was determined following Bouyoucos hydrometer (Day, 1965) and Soil pH (1: 2.5 soils to water ratio) was measured using a glass electrode pH meter as described by Peech (1965). Soil organic carbon (OC) was also determined by the chromate acid oxidation method (Walkley and Black, 1934) and soil OM was calculated by multiplying percent OC by a factor of 1.724. Total nitrogen was analyzed using the macro-Kjeldahl digestion followed by ammonium distillation and titration method (Bremner, 1965). Available Phosphorus was extracted following the Bray I method (Bray and Kurtz, 1945) and determined spectrophotometrically. Exchangeable acidity and Exchangeable aluminum (Al) were analyzed as per the method described by Sumner (1992) and Pansu et al. (2001), respectively. Cation exchange capacity (CEC) was determined following the method described by Chapman (1965).

### Experimental design and procedures

The Design was Randomized Complete Block Design (RCBD) with three replications and Plot size of 5 m × 5 m. Four treatments (1) Control (No fertilizer) (2) Recommended Nitrogen from urea+150kg/ha Minjingu organic hyper phosphate (3) Recommended NP and (4) Recommended NP + recommended lime were used in this study. 64 kg $ha^{-1}$ Nitrogen from urea and 20 kg $ha^{-1}$ Phosphorus from triple supper phosphate were used as the recommended Nitrogen (N) and recommended phosphorus (P) rate, 4.17 t/ha lime (CaO) was used as recommended lime at the study area. Urea fertilizer was applied in split application. Improved bread wheat variety, Galama (HAR-604), was used as a test crop. All management practices such as Land preparation, plowing, weeding, pesticide application and other agronomic management were carried out.

### Data collection, plant sampling

Plant height was determined by measuring the length of the plants from the ground level to the top of the spike just before physiological maturity. At physiological maturity, the plants were harvested from 3 by 3 m plot sizes close to the ground level by hand; air dried in an open dry environment. The straw and grain was determined by weighing, using sensitive balance. Grain yield per plot was determined after carefully separating the grain from the straw.

#### Data analysis

Analysis of variance was subjected to the statistical software program JMP, version 7.0 to carry out for yield and yield parameters of the crop to determine its response to the applied fertilizers and lime.

## RESULTS AND DISCUSSION

The soil reaction (pH) is classified as strong acid (pH of 4.79) according to Yuste and Gostincar (1999). The Exchangeable aluminum and Exchangeable Acid also revealed as toxic for plant growth. The total percentage of organic matter (6.83%) and total Nitrogen (0.34%) was high (Tadesse et al., 1991), while very low in available phosphorus (3.15 $mgkg^{-1}$) (Beegle and Oravec, 1990). According to Roy et al. (2006), the soil result indicated that the study area had high Cation Exchange capacity (Table 1).

### Wheat yield response to Minjingu organic hyper phosphate

The analysis of variance result showed that except days to 50% maturity and harvest index all yield and yield components(plant height, grain yield and Straw yield) of bread wheat were significantly ($P < 0.05$) affected by the treatments (Table 2).

### Wheat grain and straw yield

Application of the different fertilizer amendments resulted significant difference in grain and straw yield of wheat (Table 2). The soils that received Rec.N from urea+150 kg/ha Minjingu organic hyper phosphate, Recommended NP, and Recommended NP + recommended lime gave additional grain yield increment by about 191, 211 and 413% over the control respectively; while the straw yield improved by about 226, 248 and 422% respectively. The highest yield was recorded on soils with Recommended NP (64 Nitrogen and 20 Phosphorus kg/ha) along with lime (4.17 t/ha) followed by the Recommended NP (64 Nitrogen and 20 Phosphorus kg/ha), and soil with application of recommended N (64N) from urea+150 kg/ha Minjingu organic hyper phosphate. This indicates that liming is important in reclaiming of this acid problem to make other nutrients available to the plants in the area. Labetowicz et al. (2004) and Fageria and Baligar (2001) reported that liming is the most common soil management practice and effective for reducing soil acidity related problems and it may be beneficial as plant nutrients. This result also shows as in addition to phosphorus fertilizer, Minjingu organic hyper phosphate can use as an option in maximizing the wheat production in the area.

### Wheat plant height

The analysis of variance showed that recorded plant height was significantly affected only by the Recommended NP (64 Nitrogen and 20 Phosphorus kg/ha) + recommended lime. In soils that received Recommended NP + recommended lime considerably ($P \leq 0.05$) increased their Plant height 21.2% over the control (Table 2). This might be due to the liming effect in which plants can easily get available nutrients from the soil. A study conducted by Kidanemariam et al. (2013) also revealed that liming soils with calcium carbonate and other liming materials is important to increase production and productivity wheat of acidic soils at Tsegede highlands, Ethiopia.

## CONCLUSION AND RECOMMENDATION

In the study area where the soil is strongly acidic and toxic for plant growth results showed that except days to 50% maturity and harvest index the other yield and yield components (plant height, grain yield and straw yield) of bread wheat were significantly ($P < 0.05$) affected by the treatments. The soil that received Recommended Nitrogen (64 kg/ha) from urea+150 kg/ha Minjingu organic hyper phosphate, Recommended NP (64 kg/ha Nitrogen and 20 kg/ha phosphorus), and Recommended NP (64 kg/ha Nitrogen and 20 kg/ha phosphorus) with recommended lime (4.17 t/ha) gave additional grain yield increment by about 191, 211 and 413% over the control, respectively. However, the straw yield improved by 226, 248 and 422% respectively. The highest yield was recorded on soils with Recommended N and P (64kg/ha Nitrogen and 20kg/ha phosphorus) along with lime followed by the Recommended NP, and soil with application of recommended N from urea+150 kg/ha Minjingu organic hyper phosphate. However the recorded plant height was significantly affected by the Recommended NP + recommended lime only (increased by about 21.2%) This might be due to the liming effect in which this helps that the soil to be suitable pH for plants easily to get available nutrients from the soil. In addition to this, the Minjingu organic hyper phosphate could also be source option for phosphorus fertilizer in the acidic soils of the Tsegede highlands as well as areas with similar climate and soil conditions. Hence, uncontrolled land encroachment in the low land areas can be minimized because of making these farmlands productive.

**Table 1.** Initial Surface (0-20 cm) physical and chemical property of the experimental field.

| Texture | pH | OM (%) | TN (%) | Av. P (mg kg $^{-1}$) | Exchangeable (cmol+ kg -1) | | |
|---|---|---|---|---|---|---|---|
| | | | | | Acid | Al | CEC |
| Sandy loam | 4.79 | 6.83 | 0.34 | 3.15 | 4.17 | 3.09 | 25.38 |

Note: OM= Organic Matter; CEC= Cation Exchange Capacity; TN= Total Nitrogen and Av. P= Available Phosphorus, Al-Aluminum.

**Table 2.** One ways analysis of variance for some considered wheat yield parameters response to the application of Minjingu organic hyper phosphate.

| S/N | Treatments | Pht (cm) | G.Y(kg/ha) | S.Y(kg/ha | H.I (%) | DFM |
|---|---|---|---|---|---|---|
| 1 | Control (No fertilizer) | 73.0$^{b}$ | 548.2$^{c}$ | 799.4$^{c}$ | 40.68 | 121.3 |
| 2 | Rec.N from urea+150 kg/ha Minjingu organic hyper phosphate | 82.7$^{ab}$ | 1596.3$^{b}$ | 2610.0$^{b}$ | 37.95 | 122.3 |
| 3 | Recommended NP(64 kg/haNand20 kg/haP) | 85.5$^{ab}$ | 1707.4$^{b}$ | 2784.6$^{b}$ | 38.01 | 123.0 |
| 4 | Recommended NP + recommended lime | 88.5$^{a}$ | 2811.1$^{a}$ | 4174.7$^{a}$ | 40.24 | 123.0 |
| | SEM(±) | 2 | 65 | 83 | Ns | Ns |
| | CV | 11 | 28 | 29 | 5 | 4.5 |

Mean values across columns followed by the same letter(s) are not significantly different at P > 0.05.
NB-DFM-Days to 50% maturity, Pht (cm)-Plant height in centimeter, HI-Harvest index, G.Y (kg/ha)-Grain yield in kilogram per hectare and S.Y (kg/ha)-Straw yield in kilogram per hectare, Recommended NP=64kg/ha Nitrogen and 20kg/ha Phosphorus, Recommended lime=4.17 tone/ha.

## CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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Full Length Research Paper

# Rice insect pest management in selected rice irrigation schemes in Morogoro Region, Tanzania

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**This study was conducted in five randomly selected rice schemes in Morogoro region to obtain information on farmers' knowledge, attitude and practice in respect to management strategies undertaken for controlling insect pests both in rice fields and stores as an aid to reduce crop loss. A total of 150 farmers were randomly selected from 5 villages (30 respondents per village) and interviewed using semi structured questionnaires. Each village represented only one rice scheme. The study reveals that 61.3% of farmers cultivate rice under 0.5 to 1 acres showing that the crop is grown largely by small scale farmers. About 94.4% of farmers reported to have faced insect pest problems in rice fields with no farmer reported damage in store. It was reported that 82% of farmers control insect pests in their rice field when they notice their presence. Most of farmers (84%) used synthetic insecticides where some of them do nothing and others use non-chemical method. However, among those farmers who use pesticides, majority (83%) of them reported that they have never attained any training on the proper handling and application of chemicals suggesting a need for trainings to farmers on how to handle pesticides.**

**Key words:** Rice, scheme, insect, management.

## INTRODUCTION

Rice (*Oryza sativa* L.) is the staple food of over half the world's population which its demand is increasing in many countries (Hegde and Vijayalaxmi, 2013). It has been reported as the fundamental principal food supplying 20% of the calories consumed worldwide (Kubo and Purevdorj, 2004; Liu et al., 2010). The contribution of rice on per capita calories in the developing countries is around 27% (Awika, 2011). However, Basorun and Fasakin (2012) reported that there is an increase on rice consumption in Asia and Africa. The authors further reported that in many countries of Africa, rice constitutes a major part of the diet (Basorun and Fasakin, 2012). Report by Luzi-Kihupi et al. (2009) show that importance of rice in Tanzania is increasing with its consumption estimated to be 232.7 kg per year per person.

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**Table 1.** Background information of the respondents (%) (n = 150).

| Category | Responses | Kilosa | | Morogoro rural | | Mvomero | |
|---|---|---|---|---|---|---|---|
| | | Ilonga (n=30) | Mvumi (n=30) | Kiroka (n=30) | Mbarangwe (n=30) | Mkindo (n=30) | Average |
| Age (Years) | 20-30 | 10 | 4 | 9 | 7 | 19 | 10 |
| | 31-40 | 44 | 28 | 41 | 36 | 26 | 35 |
| | 41-50 | 25 | 24 | 36 | 25 | 30 | 28 |
| | 51-60 | 21 | 16 | 9 | 21 | 19 | 17 |
| | Above 60 | 0 | 28 | 5 | 11 | 6 | 10 |
| Sex | Male | 52 | 65 | 41 | 55 | 64 | 55 |
| | Female | 48 | 35 | 59 | 45 | 36 | 45 |
| Education level | Illiterate | 0 | 23 | 0 | 14 | 7 | 8.8 |
| | Primary | 93 | 73 | 100 | 79 | 89 | 86.8 |
| | Secondary | 7 | 0 | 0 | 7 | 4 | 3.6 |
| | Beyond Secondary | 0 | 4 | 0 | 0 | 0 | 0.8 |

Regarding to rice production in East, Central and Southern Africa (ECSA) region, Tanzania has been reported as the second largest producer and consumer after Madagascar (Benard et al., 2014; URT, 2009). The average production level reported in Tanzania is 818,000 tonnes per year (Benard et al., 2014; URT, 2009). This amount is produced from five regions which are Shinyanga, Mwanza, Morogoro, Mbeya and Tabora with some supplementary production coming from Manyara, Singida and Dodoma lands.

However, rice production in Tanzania continues to be low at 1 to 1.5 t $ha^{-1}$ due to several factors such as lack of improved varieties, drought, poor weed control programs, insect pests, diseases and lack of effective disease control techniques (Luzi-Kihupi et al., 2009).

It has been reported that insect pests, for example stem borers, have been reported to cause crop damage to about 34.9% indicating its importance on reducing crop productivity in Tanzania (Mihale et al., 2009). Tengo and Belfrage (2004) reported that most of the research on rice has been focusing mainly on agronomic and breeding perspectives with little emphasis on rice insect pest management. This study therefore, aimed at investigating the damage caused by insect pest to rice crop and understands the management options and practices by farmers for reducing the associated damage.

## MATERIALS AND METHODS

### Study sites

The study was conducted in three districts of Morogoro region from October to December, 2014 where five rice schemes were selected, namely, Mvumi and Ilonga schemes located in Kilosa district, Mkindo scheme located in Mvomero district, and Kiroka and Mbarangwe schemes located in Morogoro rural district. In these schemes, where rice is an important source of food and income generation (Mwingira et al., 2009), farmers practice rain-fed and irrigated rice farming.

### Sampling procedures and data analysis

Thirty rice farmers were randomly selected from each scheme for interview. Standard prepared questionnaires were used to seek information on farmers' knowledge, attitude and practice on insect pest management in rice growing areas. Basic questions on size of land owned, size of farms under rice cultivation, rice production constraints with more focus on insect pest problems, estimated crop damage, and insect pest control measures were addressed. During the interview, pictures for un-named rice insect pests were provided to farmers for reference on identification to what type of insects involved for rice damage in their fields or storage. The collected data were analysed using SPSS software version 16.

## RESULTS

### General farmers characteristics

Information from 150 farmers intervewed show that, 45% were female and the rest 55% were male (Table 1). Majority of respondents had their age ranging from 21 to 60 years and their education ranged from primary education, secondary education, beyond secondary education while others were illiterate (Table 1).

### Rice production and land under rice farming

Results show that most farmers (61.3%) cultivate rice on small pieces of land ranging from 0.5 to 1 acre whereas 24, 10.9 and 3.8% cultivate rice in 1.5 to 2, respectively. Regarding to rice production it was reported that vast number of respondents (43.1%) produce 6 to 10 bags (each bag 100 kg) per acre. However, only 0.8% produce

**Table 2.** Constraints faced by rice farmers in selected five rice schemes in Morogoro Region (n= 150).

| Constraints | Percentage respondents per rice scheme | | | | | Average |
|---|---|---|---|---|---|---|
| | Ilonga | Mvumi | Kiroka | Mbarangwe | Mkindo | |
| Rice insect pests | 27.27 | 20.48 | 42.86 | 28.57 | 22.39 | 28.3 |
| Rodent pests | 32.47 | 28.92 | 32.65 | 39.68 | 34.33 | 33.6 |
| Shortage of water for irrigation | 19.48 | 4.82 | 12.24 | 20.63 | 0.00 | 11.4 |
| High price of inputs | 5.19 | 3.61 | 2.04 | 6.35 | 13.43 | 6.1 |
| Delay of agricultural inputs | 6.49 | 0.00 | 0.00 | 0.00 | 7.46 | 2.8 |
| Rice diseases | 2.60 | 16.87 | 4.08 | 0.00 | 5.97 | 5.9 |
| Destruction from livestock | 2.60 | 2.41 | 0.00 | 4.76 | 2.99 | 2.6 |
| Birds | 2.60 | 18.07 | 2.04 | 0.00 | 2.99 | 5.1 |
| Weeds | 1.30 | 2.41 | 4.08 | 0.00 | 1.49 | 1.9 |
| Lack of capital | 0.00 | 2.41 | 0.00 | 0.00 | 8.96 | 2.3 |
| Total | 100 | 100 | 100 | 100 | 100 | 100.0 |

31 to 35 bags and the lowest production of 1 to 5 bags produced by 17.7% of farmers. It was further observed that more than half of all respondents (52.6%) practise irrigation as their main rice framing system, whereas 33.8% practised both rainfed and irrigation, only a few farmers (13.6%) practised rainfed system. With regard to sources of rice seeds, 45.9% farmers obtain the seeds from their own store where 29.3, 18.8 and 6% of farmers obtain seeds from other farmers, voucher system, and agricultural seed agencies, respectively. However, our results show that most of farmers 54.9, 35.3, 8.3 and 1.5% who grew two, one, three and more than three rice varieties, respectively.

## Rice production constraints

Reports by farmers show that majority of respondents from Ilonga, Mvumi, Kiroka, Mbarangwe and Mkindo schemes experience rice production constraints with few who reported to have not experienced rice problem in their fields. In general, the reported major six rice problems were rodent pests (33.3%), rice insect pests (28.3%), shortage of water for irrigation (11.4%), high price of inputs (6.1%), rice diseases (5.9%), birds (5.1%) and other minor constraints as shown in Table 2.

## Estimated rice crop damage caused by insect pests

Results show that 23.9% of farmers experienced crop damage ranging from 41 to 50%, while 23% of farmers estimated damage at 21 to 30% and other farmers (17.7%) experienced damage at less than 20%. About 17.7% of farmers were not aware of the damage, while 10.6% of farmers experienced damage of 31 to 40%. In addition, only few farmers (7.1%) reported crop damage of above 50%. However, some few farmers (17.7%) reported that they were not aware of the amount of damage the insect caused to their rice in field.

In regard to the rice variety responses on insect pest damage, majority of respondents (73.6%) reported that all rice varieties grown in their scheme were vulnerable to insect pest damage. Basing on effect of cropping season, significant difference ($p<0.001$) on crop damage was observed where rice crop grown during dry seasons experienced more damage compared to rain fed rice crop.

Result shows that majority (54%) of farmers reported rice crop damage occurring in dry season while the remaining (46%) reported that the damage occurs in both rain fed and dry season. However, when farmers were asked about the most affected rice growth stage, most of farmers 64.8% reported that the most crop stage at risk was after rice transplanting. Other stages example nursery and flowering stages was 15.6 and 11%, respectively. There was few responses (1.9%) reporting on crop damage at maturity stage. Report on insect pest damage on stored paddy showed that all respondents (100%) were not aware of the damage occurring in stores and that they had not experienced any damage.

## Common rice insect pests in the study areas

Results show that most farmers (33%), reported stalk eyed fly followed by rice grasshopper as the most damaging rice insect (Figure 1). Other insect pests which were mentioned by farmers that contribute to lower rice production are shown in Figure 1.

## Rice insect pest management

Results show that majority of rice farmers (82%) took action in controlling insect pests so as to reduce crop damage whilst the rest 18% did not control. With regard to control techniques use, most of respondents (84%)

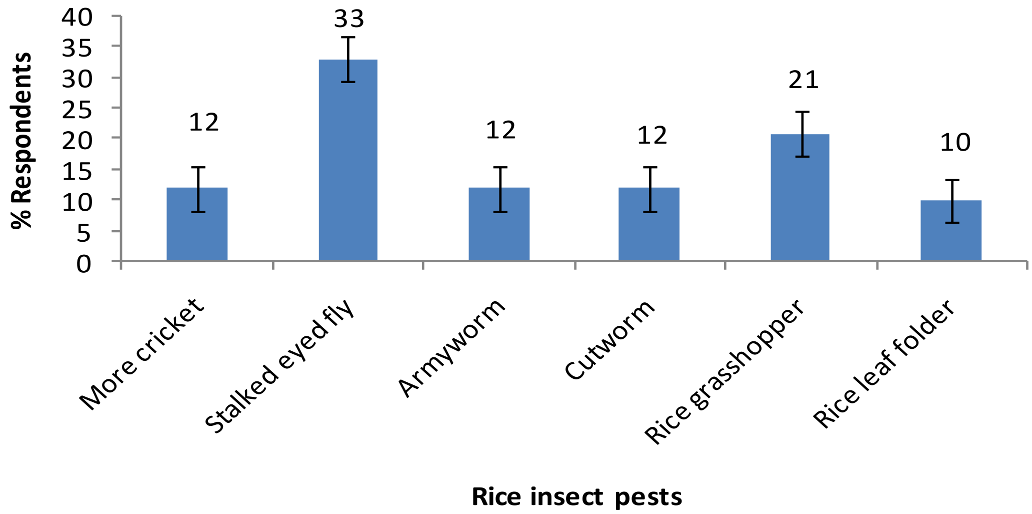


**Figure 1.** Responses on common rice insect pests in selected rice schemes in Morogoro region (n = 150).

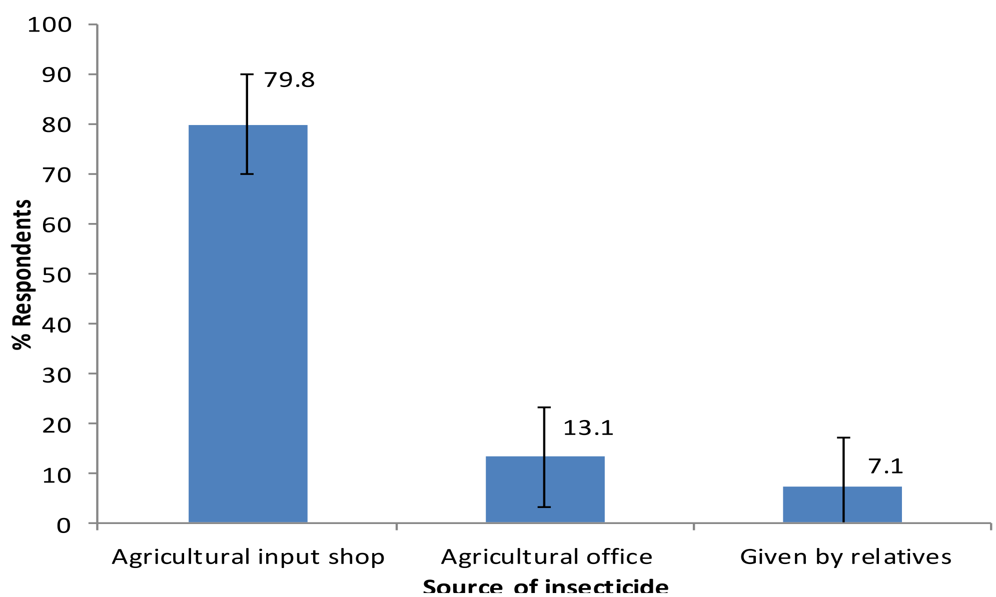


**Figure 2.** Sources of chemical applied by farmers for rice insect pest control (n=150).

reported to use chemicals while 16% used non chemical insect control techniques. When those respondents using chemical control were asked on the kind of insecticides used, most of farmers reported to use Karate (40.2%), Thionex (14.4%), Selectron (12.4%) and Attakan (2.1%). However, some farmers (10.3%) did not remember the chemical they used while 20.6% did not know the chemical at all.

Agricultural input shops were the main source of insecticide (79.8%) (Figure 2) and the cost incurred by those farmers who use insecticides are as shown in Table 3. Although farmers reported to use insecticides, only 16.7% reported to have been trained on proper application of insecticides while 83.3% were not trained any more. Results on those farmers attained training shows that majority of respondents (8%) were trained 2 to 5 years (Figure 3).

## DISCUSSION

In the current study, it was observed that most of farmers

**Table 3.** The cost incurred by farmers for rice insect pest management using chemical control method (n = 150).

| Control costs (Ts) spent by farmers | Percentage respondents |
|---|---|
| 5000-10,000Tshs | 62.2 |
| 11,000-15,000Tshs | 11.1 |
| 16,000-20,000Tshs | 6.7 |
| 21,000-25,000Tshs | 2.2 |
| Don't remember | 2.2 |
| Total | 100.0 |

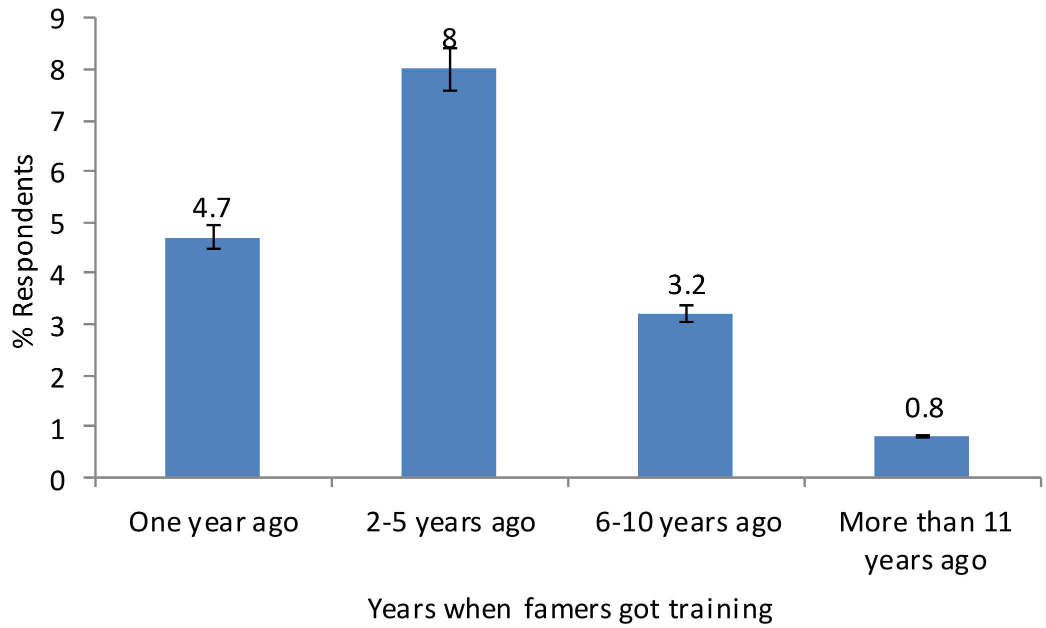


**Figure 3.** Time when farmers got training on application of insecticides (n=150).

used very small plots for rice production ranging from 0.5 to 1 acre. This amount of land is small compared to that reported by Wolter (2008), that the land sizes for smallholder farmers in Tanzania range from about 2.0 to 7.5 acres (or about 0.9 to 3 ha). However, our results are similar to reports by Sokoni (2008) and Mulungu et al. (2015) that smallholder farmers in Tanzania use small and fragmented plots for crop production. Studies by Mung'ong'o and Mwamfupe (2003), show farmers practice subsistence farming where crop cultivation is done for home consumption and this could be the reason why farmers in the study area cultivate small plots for rice production.

With regard to farming season, most farmers reported to practice irrigated rice farming with exception of few who depend on rainfall alone and others reported to depend on both rainfall and irrigation. CONCERN Worldwide (2008) pointed out that irrigation has been a significant aspect among rice farmers. In addition, previous studies by Kato (2007), Kangalawe and Liwenga (2005) and Ngaga et al. (2005), revealed that wetlands are potential in rice crop production.

Our results however, are different from that of Musamba et al. (2011) who reported that few farmers (22.3%) in Kilombero district practiced rice irrigation farming where majority (41.7%) of the households depends on both rain-fed and irrigation in crop production with 36% farmers depending on rain-fed agriculture only.

With regard to rice production constraints, our study found that rice farmers faced problems resulting from insect pests, rice diseases, drought, high prices of inputs and rodent pests. Insect pest was among the most constraint mentioned by farmers where all rice varieties grown by farmers were reported to be damaged by insect pests resulting into rice yield loss and ultimately poor economic return from farmers investment. Similar reports on insect pest damage to rice crop were reported by CFC (2012) and Kadigi et al. (2008) who identified two kinds of constraints facing rice production in Tanzania, namely, biotic and abiotic. According to Musamba et al. (2011), biotic and abiotic constraints together reduce crop production and have been major obstacles for rice productivity in many areas of Tanzania. Report by IRRI et al. (2010) shows an estimation of rice yield loss due to insects in Africa ranging between 10 and 15%.

This study observed that, farmers considered stalk eyed fly, rice grasshopper, cutworm, armyworm and more cricket as the dominant insect pest threatening rice in field. The results are comparable to that of Nonga et al. (2011) which identified pests like aphids, thrips, beetles, foliar feeding caterpillars, mites, borers, cutworms, bollworms, bugs, whiteflies and leafhoppers in Manyara region.

It was reported that the most affected rice crop stage was after transplanting at high damage level with moderate damage during nursery and flowering stages. Similar result was reported by Nwilene et al. (2013) that insect pests cause considerable rice crop losses in the field and in storage. Suggestion by Nonga et al. (2011) show that farmers' knowledge and experiences on the stage at which their crops are damaged is vital since it facilitates appropriate timing to apply pesticides.

With regard to insect pest control measures used by farmers, our study found that some farmers take immediate action on rice insect pests to reduce the estimated rice damage. Most farmers used insecticides a practice which is similar to the report by Nonga et al. (2011). The authors reported that the use of chemical pesticide has become a common practice to control pests and diseases in crops cultivated in Tanzania. However, the limiting factor on proper use of insecticides is limited knowledge on the application of insecticides in their farming activities. This could be due to poor education background as was reported that most of farmers in the studied schemes were primary school leavers who could not understand pesticide labels written in English. In addition, our result also revealed that, most of farmers were not trained on the best use of the insecticides and their disposal to avoid the possible effects to the environment.

Report by Edmeades (2003) show that, the increased use of organic pesticides which apart from increasing crop production, have long term negative effects on Fauna and flora, which will then change soil characteristics and hence reduced production. Similar report by Ntow et al. (2006) stipulates that the reasons for pesticide misuse and improper handling are lack of knowledge by farmers and inadequate extension services. However, majority of farmers in the study area have shown an interest on need for training on better handling and application of insecticides for insect pest control on their rice crops.

## CONCLUSION AND RECOMMENDATION

It has been observed in this study that farmers used largely chemical control method for insect pest management so as to avoid the damage and crop losses which would ultimately reduce crop productivity. However, most farmers had little knowledge on how to apply the chemicals which might contribute to environmental pollution and hence affecting beneficial insects in fields. Therefore, this study recommends on provision of trainings to farmers on safe use of agrochemicals. It also recommends that further studies especially field experimentation be carried out to verify the amount of damage caused by specific insect pest at specific season. Furthermore, field observation should be done to identify how farmers apply insecticides and evaluate the effectiveness of each of the insecticides against specific insect pest.

## CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

## ACKNOWLEDGEMENTS

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# Evaluation of dry matter yield, yield components and nutritive value of selected alfalfa (*Medicago sativa* L.) cultivars grown under Lowland Raya Valley, Northern Ethiopia

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**The experiment was conducted at Raya Azebo district, which is located in Southern Tigray, North Ethiopia, with the objective to investigate the highest dry matter yield and herbage nutritive value among the selected alfalfa cultivars. The experiment was conducted by randomized complete block design with four replications and five cultivars. The experimental cultivars were FG-10-09 (F), FG-9-09 (F), Magna-801-FG (F), Magna-788 and Hairy Peruvian. Harvesting cutting intervals was taken at an average of 57.78±4.78 days of mid flowering at irrigation land. A total of 4 cutting cycles were taken from January 2016 to August 2016. The result of the study showed that dry matter (DM), organic matter (OM), crude protein (CP), neutral detergent fiber (NDF) and *in vitro* dry matter digestibility (IVDMD) was comparable across the five cultivars. Stand height was significant different (P<0.001) among the cultivars. Alfalfa cultivars FG-10-09(F), FG-9-09(F), Magna-788 and Hairy Peruvian had significantly (P<0.001) higher plant height as compared to Magna-801-FG (F). However, DM yield and leaf to steam ratio (LTSR) was not affected by cultivars (P>0.05). Cutting cycle significantly affected stand height, DM yield and LTSR. Plant height and DM yield were significantly different (P<0.001) among the cultivars across the cutting cycle. Cutting cycles 2, 3 and 4 had the highest stand height and DM yield as compared to cutting cycle 1 (P<0.001). But, cutting cycles 2 and 1 were significantly higher in LTSR as compared to 3 and 4 (P<0.001). Therefore, it can be conclude that all the cultivars evaluated had not shown significant difference in DMY and nutritive content, but Hairy Peruvian had relatively good DM yield and higher stand height, as a result, it is good to promote Hairy Peruvian cultivar for further demonstration and seed production.**

**Key words:** Alfalfa, dry matter yield, nutritive content, cutting cycle, leaf to stem ratio.

## INTRODUCTION

Feed scarcity in both quantitative and qualitative dimensions is one of the major constraints for the promotion of the livestock subsector in Ethiopia (Alemu, 1997). In many areas of the country, animals are kept on poor quality natural pasture that commonly occur on permanent grasslands, roadsides, pathways and spaces

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between cropped plots (Tewodros and Meseret, 2013). Such low quality feeds are associated with a low voluntary intake, thus resulting in insufficient nutrient supply, low productivity and even weight loss (Hindrichsen et al., 2001). Effective methods through which utilization of low quality roughages could be improved include supplementation with energy and nitrogen sources, chemical or physical treatment, and selection and breeding of crops, each of which ultimately depends on the economic benefits and applicability (McDonald et al., 2002). One way to optimize utilization of available feed resources is strategic supplementation of crop residues with plant protein sources such as leguminous forage crops which have the potential for alleviating some of the feed shortages and nutritional deficiencies experienced in the dry season on smallholder farms (Hove et al., 2001; Teferedegne, 2000). As a result, animals with access to leguminous forage crops perform better than those kept on natural pasture in milk yield, weight gain, reproductive performances and survival rates (Elbasha et al., 1999; Norton, 1994b).

In Ethiopia, more attention, however, has been given to assessment of the environmental adaptation, herbage DM yield potential and seed bearing ability of candidate accessions, while data on their nutritive value is generally scarce (Geleti et al., 2014). Alfalfa has one of the highest crude protein contents among forage crops, but it is rapidly and extensively degraded by rumen microorganisms (Dong et al., 2009). It can produce around 25% more dry matter than pasture (Richard, 2011) and Yields of irrigated alfalfa have been shown to be up to 24 ton DM yield $ha^{-1}$ $year^{-1}$ (Brown et al., 2000). There are numerous cultivars of alfalfa, selected for specific abilities, such as winter hardiness, drought resistance, tolerance to heavy grazing or tolerance to pests and diseases (Frame, 2005). Selection of important cultivars in Ethiopia, has been given to assessment of the environmental adaptation, herbage DM yield potential and seed bearing ability of candidate cultivars (Geleti et al., 2014). Moreover, these five cultivars used in the current study were grown under different production systems and agro-ecological conditions in Ethiopia. As a result, testing the same cultivars in different agro-ecological zones has been an advantage to find suitable cultivars specifically to the study area. Therefore, this study was initiated to investigate the highest dry matter yield and herbage nutritive value among the selected five alfalfa cultivars in lowland agro ecology area of Raya value.

## MATERIALS AND METHODS

### Description of the study area

The study was conducted at Raya-Azebo district, Wargiba research site. The area is located at a distance of 660 km from Addis Ababa (capital city of Ethiopia) to the North and 120 km far from Mekelle (capital city of Tigray regional state) to south direction. The altitude of the area is 1600 m above sea level. Geographically, it is located between 12.32-12.95°North latitude and 39.56-39.98°East longitude. The temperature of the district is within the range of 22 to 26°C. The mean annual rainfall is 600 mm and within the range of 400 to 800 mm. The distribution of the rainfall is the temporal situation and shows bimodal event. The area covered a total of 85% categorized as the mid land agro ecology and 15% covers a low land agro ecology. From February to April the rainfall is commonly little rain, but the main rain season is between July and September (OARD, 2016).

### Experimental design and treatments

The experiment was conducted by randomized complete block design (RCBD) with four replications and five treatments. Each alfalfa cultivars were assigned randomly for each block. The cultivars were evaluated at Alamata Agricultural Research Center, Wargba Research site at irrigated land. The experimental treatments used were FG-10-09 (F), FG-9-09 (F), Magna-801-FG (F), Magna-788 and Hairy Peruvian. The cultivars were planted in a plot size of 9 $m^2$ (3 m × 3 m), and spacing between rows and blocks 0.2 and 1 m, respectively. The seed rate used in the experiment was 10 kg $ha^{-1}$ and sowed drilled within the row. With this after sown the soil was slightly covered carefully and 100 kg $ha^{-1}$ of DAP was applied during sowing. Water was supplied every week and in every cutting hoeing applied. The other management practice like weeding, cutting and protection managements were done carefully as important.

### Stand height, dry matter yield and leaf to stem ratio

Determination of stand height, dry matter yield and leaf to stem ratio data was recorded. Mean stand height of five randomly selected plants from a plot was recorded. The data of the plant height was taken at the stage of herbage biomass harvesting. Leaf to stem ratio was determined from the same sampling area of fresh biomass, after taking the sample of 300 g for dried DM yield. Then after, the harvested biomass was partitioning into leaf and stem fractions, and drying the fraction samples using similar procedures described above for herbage DM yield determination. From the total area of 9 $m^2$ plots, a net area of 1.8 $m^2$ was harvested randomly from three selected adjacent middle rows to estimate the fresh biomass yield and sample for DM yield. The fresh biomass was recorded after cutting using sickle and weighing using spring balance. To determine DM yield, 300 g sample was taken and dried in an oven at 65°C for 72 h. The harvested stage for estimation of good biomass and nutritive value was followed by Ball (1998), explained as a stage when open flowers emerge on average of 2 or more nodes and no seed pods present at the stage of full flowering stage.

### Cutting intervals of herbage yield

With increasing alfalfa maturity in regrowth cycle, forage nutrient concentrations decrease while forage dry matter yield increase to about mid-flowering (Radović et al., 2009). To compromise, these yield and nutritive value, harvesting cutting intervals in this study was taken at an average of 57.78±4.78 days of mid flowering at irrigation land. A total of 4 cutting cycle were taken from January 2016 up to August 2016.

### Relative feed value

Relative Feed Value (RFV) is an index used to rank feeds relative

**Table 1.** Chemical composition, *in vitro* DM digestibility and RFV of selected alfalfa cultivars.

| Cultivar | DM (%) | Ash (%) | CP (%) | OM (%) | NDF (%) | ADF (%) | ADL (%) | IVDMD (%) | RFV |
|---|---|---|---|---|---|---|---|---|---|
| FG-10-09(F) | 91.43 | 13.73 | 17.48 | 86.27 | 39.49 | 28.56 | 5.74 | 76.96 | 121.33 |
| FG-9-09(F) | 92.09 | 12.58 | 16.34 | 87.42 | 42.31 | 31.09 | 6.15 | 72.61 | 110.88 |
| Magna-801-FG (F) | 90.74 | 13.02 | 17.7 | 86.98 | 39.29 | 29.28 | 5.25 | 76.68 | 120.74 |
| Magna-788 | 90.91 | 13.78 | 19.37 | 86.22 | 39.74 | 26.88 | 3.62 | 79.53 | 123.25 |
| Hairy Peruvian | 90.88 | 13.28 | 18.3 | 86.72 | 38.75 | 30.56 | 6.33 | 73.58 | 120.15 |

DM = Dry matter, OM = Organic matter, CP = Crude protein, NDF = Neutral detergent fibre, ADF = Acid detergent fiber, ADL = Acid detergent lignin, IVDMD= Invtro dry matter digestibility, and RFV= Relative feed value.

to the typical nutritive value of full bloom alfalfa hay, containing 41% ADF and 53% NDF on a DM basis, and having a RFV of 100, which is considered to be a standard score. This index is widely used to compare the potential of two or more forages on the basis of energy intake (Schroeder, 2013).

RFV = DDM (%DM) × DMI (%BW) / 1.29

where DDM is digestible dry matter, DMI is dry matter intake potential as % of body weight, and BW is body weight were calculated from ADF and NDF as followed (Uttam et al., 2010):

DDM (%DM) = 88.9-0.78 × ADF (%DM)

and

DMI (%DM) = 120 / NDF (%DM)

#### Chemical analysis

Chemical composition of the cultivars were prepared from each replication and then finally pooled as one cultivar within each cutting cycle. The dry matter (DM%), crude protein (CP%) (Nx6.25) and ash were determined using the standard procedures of AOAC (1990). The neutral detergent fiber (NDF%), acid detergent fiber (ADF%) and acid detergent lignin (ADL) fractions were analyzed according to Van Soest (1994). The modified Tilley and Terry *in vitro* method (Van Soest and Robertson, 1985) was used to determine the *in vitro* dry matter digestibility (IVDMD).

#### Statistical analysis

The data obtained from the experiment was subjected to analysis of variance using the General Linear Model Procedure of SAS (1998). Significant treatment mean was separated using Tukey HSD. The model used for the analysis of all parameters was:

$Y_{ijk} = \mu + a_i + b_j + e_{ijk}$

where $Y_{ijk}$ = response variable, $\mu$ = overall mean, $a_i$ = $i^{th}$ treatment effect, $b_j$ = $j^{th}$ block effect, and $e_{ijk}$ = random error.

## RESULTS

### Chemical composition and *in vitro* DM digestibility of alfalfa cultivars

Chemical composition and *in vitro* DM digestibility of alfalfa cultivars are shown in Table 1. The study showed that the DM content was comparable across the five cultivars. Similarly, the CP content of the present study also indicated comparable result within the treatments. The fiber (NDF, ADF and ADL) value of the experimental cultivars showed similar contents within the treatments. Likewise, the results of *in vitro* dry matter digestibility (IVDMD) content were also comparable across the five cultivars.

### Stand height, leaf to stem ratio and dry matter yield

Stand height, dry matter yield and leaf to steam ratio of five alfalfa cultivars are shown in Table 2. The present study showed that plant height was significance differences (P<0.001) among the five cultivars. Alfalfa cultivars FG-10-09 (F), FG-9-09 (F), Magna-788-FG (F) and Hairy Peruvian had significantly (P<0.001) higher plant height as compared to Magna-801. However, DM yield and leaf to steam ratio (LTSR) was not affected by the cultivars (P>0.05).

### Dynamics of forage production across cutting cycles

Cutting cycles of stand height, DM yield and leaf to stem ratio of selected alfalfa cultivars are shown in Table 3. Cutting cycle was significantly affected by stand height, DM yield and LTSR. Stand height and DM yield were significantly different (P<0.001) among the cultivars across the cutting cycle. Cutting cycles 2, 3 and 4 had the highest stand height and DM yield as compared to cutting cycle 1 (P<0.001). This might be due to additional tillers which created an impact on the increment of DM yield included in the other cutting cycles as compared to the 1st cutting cycle. But, cutting cycles 2 and 1 were significantly higher than LTSR as compared to 3 and 4 (P<0.001).

## DISCUSSION

### Nutritive value of alfalfa cultivars

As Kazemi et al. (2012) reported high quality alfalfa had

**Table 2.** Stand height (cm), dry matter yield ($tonha^{-1}$) and leaf to steam ratio of selected alfalfa cultivars across year.

| Cultivar | Stand height | DMY | LTSR |
|---|---|---|---|
| FG-10-09(F) | $78.0^{a}$ | 4.59 | 0.77 |
| FG-9-09(F) | $71.5^{ab}$ | 3.96 | 0.87 |
| Magna-801-FG(F) | $66.6^{b}$ | 3.98 | 0.93 |
| Magna-788 | $72.3^{ab}$ | 4.49 | 0.79 |
| Hairy Peruvian | $79.6^{a}$ | 4.81 | 0.83 |
| SEM | 0.03 | 0.27 | 0.06 |
| P-level | *** | NS | NS |

[abc]Means within the same rows bearing a common superscript not significantly, ***(P<0.001), **(P<0.01), *(P<0.05), DMY=Dry matter yield, LTSR= Leaf to steam ratio, SEM= Standard error of mean, NS= Not significance.

**Table 3.** Effect of cutting cycles on stand height (cm), DM yield ($ton\ ha^{-1}$) and leaf to stem ratio of selected alfalfa cultivars.

| Cutting cycle | Stand height | DMY | LTSR |
|---|---|---|---|
| Cycle 1 | $58.7^{b}$ | $5.38^{b}$ | $0.60^{ab}$ |
| Cycle 2 | $78.1^{a}$ | 6.59a | $0.61^{a}$ |
| Cycle 3 | $84.3^{a}$ | 6.81a | $0.54^{b}$ |
| Cycle 4 | $82.9^{a}$ | 7.23a | $0.53^{b}$ |
| SEM | 0.02 | 0.18 | 0.02 |
| P-level | *** | *** | *** |

[abc]Means within the same columns bearing a common superscript not significantly, ***(P<0.001), **(P<0.01), *(P<0.05), DMY=Dry matter yield, LTSR= Leaf to steam ratio, SEM= Standard error of mean, NS= Not significance.

to contain <40% NDF, <31% ADF and >19% CP in general, but particularly at full bloom stage alfalfa forage had to contain a CP>16%, ADF <41%, NDF <53% and RFV >100%. With this threshold of the aforementioned report, the nutritive value of the cultivars in the present study had fulfilled the full bloom stage. In addition, the fibrous content of FG-10-09(F), Magna-801-FG (F), Magna-788 and Hairy Peruvian also contains high rank quality alfalfa content unlike, the CP content. However, Hairy Peruvian cultivar in the present study had scored high quality alfalfa with the threshold content of CP%, NDF% and ADF%. The differences in nutritive value might have occurred due to many factors: harvesting management, varieties and harvest frequency. This implies that cutting at earlier stages might improve the crude protein content and decrease fiber content, but at the expense of yield (Dennis and Howard, 1993).

The current study also ranged comparable result of the quality of alfalfa hay reported by Redfearn and Zhang (2011) as the first prime NDF < 40-46, ADF < 31-40, CP% >17-19 and RFV <125-151. The cultivars FG-10-09(F), Magna-801-FG (F), Magna-788 and Hairy Peruvian had a value of NDF 39.49, 39.29, 39.74 and 38.75%, respectively which facilitates the rate of passage unlike, FG-9-09(F) cultivar resulted in 42.31% NDF with greater than the bench mark. This result was comparable with Găvan et al. (2013) where NDF levels greater than 40% begin to slow rate of passage down, creating a gut-fill effect. This resulted in lower dry matter intake as higher gut-fill occurred. In general, between yield and nutritive value, the greatest impact on timing of harvests made in spring and early summer in humid environments, and in early and late summer in more arid regions led to negative association (Brink et al., 2010).

The DM content of the current study was comparable with Gashew et al. (2015), while higher DM content was indicated as compared to Geleti et al. (2014) for the same cultivars. The DM (%) content of FG-10-09(F) was comparable with the report of Walie et al. (2016), but the other four cultivars of the current study had less DM (%) content as compared to the same author. *In vitro* dry matter digestibility (IVDMD) ranged from 73.58 to 79.53% in this study showed less value as compared to the report of Diriba et al. (2014) which ranged from 83.07 to 87.35%, but higher value of IVDMD was recorded as compared to Walie et al. (2016) ranging from 61.58 to 62.37%. Similarly, small value of IVOMD were also reported for 14 alfalfa varieties, with values ranging from

59.15 to 66.33% (Kamalak et al., 2005) with less value as compared to the current study. The differences in IVDMD might occur from the time of harvesting. As the lignin levels increase with maturity in stems, digestibility will decrease in many forage crops such as alfalfa, because lignin concentration correlates negatively with forage digestibility (Dianging et al., 2001).

Relative feed value (RFV) has been used for years to compare the quality of legume and legume/grass hays and silages (Peter and Alvaro, 2004). As Moore and Undersander (2002a) demonstrated, forages with RFV greater than 100 are of higher quality than full bloom alfalfa hay, and forages with a value lower than 100 are of lower value than full bloom alfalfa. The RFV index of the cultivars of the current study indicated greater than the threshold of 100, which illustrated the cultivars to have higher quality standard. This RFV was proposed to reflect how well an animal will eat and digest a particular forage species when it is fed as the only source of energy (Kazemi et al., 2012). However, the RFV index of this study indicated lower value ranged from 110.88 to 123.25 as compared to Diriba et al. (2014) whose report ranged from 154.01 to 189.55 for the same cultivars. In general, the result of the current study id ranked 2nd prime standard quality classification as reported by Redfearn and Zhang (2011) as 1st and 2nd prime ranging from CP(17-19%), NDF(40-46%), ADF(31-40%) and RFV (125-151), and CP(14-16%), NDF(47-53%), ADF(36-40%) and RFV (103-124), respectively.

## Stand height, leaf to stem ratio and dry matter yield

Alfalfa forage production may be related to plant density, disease resistance, cutting cycle and cultivar difference (Cook et al., 2005). The stand height of the current study was significantly different ($P<0.001$) among cultivars. This result was true with the report of Walie et al. (2016) and Diriba et al. (2014) for the same selected alfalfa cultivars. Hairy Peruvian showed higher stand height (79.6 cm) as compared to the other cultivars. Agreed with the study by Diriba et al. (2014) and Heuzé (2013) who reported that, Hairy Peruvian had higher stand height as compared to respective evaluated cultivars, but superior stand height for this cultivar shown as compared to the current study (86.5 cm and 1 m), respectively. On the contrary, Walie et al. (2016) had indicated higher stand height for FG-9-09(F) as compared to the other cultivars. In general, stand height of the current study lay in the range of different scholars for different cultivars (Turan et al., 2017; Walie et al., 2016; Diriba et al., 2014; Taherian, 2009).

Leaf to stem ratio (LTSR) of the current study had no significant differences ($P>0.05$) among the cultivars, this was comparable with the report of Diriba et al. (2014) and Afsharamanesh (2009) unlike, Gashaw et al. (2015) for the same alfalfa cultivars. While, the evaluated value of LTSR alfalfa cultivars in the present study ranged from 0.77 to 0.87 and it was inferior as compared to the value reported by Diriba et al. (2014) ranging from 0.95 to 1.21 for the same cultivars. This might have occurred due to the difference of soil type, management and harvesting stage. Similarly, Katic et al. (2006) reported that the proportion of leaves and stems in alfalfa hay can vary greatly, depending on maturity at harvest, cultivars, handling, and rain damage. Among the evaluated selected alfalfa cultivars, Magna-801 FG (F) had superior LTSR in the current study. Leaf to stem ratio is an important trait in the selection of appropriate forage cultivar as it is strongly related to forage quality (Sheaffer et al., 2000). Alfalfa leaves have significantly higher nutritive value than stems, so to advance forage quality has been to develop cultivars which possess a greater proportion of leaves than steam (Ray et al., 1999a). Because, leaves have a stable protein content that is much higher than that of the stems. Stem develops at the expense of leaves and their cell walls and lignin content increases with maturity (Veronesi et al., 2010).

Dry matter yield (DMY) of the present study does not show any significant differences among the cultivars ($P>0.05$), and this agreed with the result reported by Gashaw et al. (2015) for the same cultivars. Unlike this finding, other reports observed significant different among cultivars (Turan et al., 2017; Walie et al., 2016; Diriba et al., 2014). The DMY of the current study ranged from 3.96 to 4.81 ton $ha^{-1}$, which was comparable to Basafa and Taherian (2009), Geleti et al. (2014), Befekadu and Yunus (2015), and Walie et al. (2016) reported a values of 2.84-4.23, 4.22-4.77, 4.12 and 4.00-4.87 ton $ha^{-1}$ for different cultivars, respectively. But, Gashaw et al. (2015) reported inferior result (2.4-2.8) ton $ha^{-1}$ for the same cultivars with the aforementioned scholars and the present study. The difference in value of dry matter yield (DMY) might be observed due to the attributed varietal or environmental and/or their interaction differences reported (Diriba et al., 2014). In this study, Hairy Peruvian showed relatively higher DMY as compared to FG-10-09, FG-9-09, Magna-788 and Magna-801, but in other scholars, FG-9-09 cultivar had scored higher DMY as compared to FG-10-09(F), Hairy Peruvian, Magna-788 and Magna-801-FG(F) (Gashaw et al., 2015; Diriba et al., 2014). This yield differences might be due to the growth stage, leaf to stem ratio, moisture conditions at harvest and processing method (Veronesi et al., 2010).

## Dynamics of forage production across cutting cycles

Stand height and DMY of the present study showed highest values at cutting cycles of 2, 3 and 4 as compared to the 1st cutting. However, for LTSR there was no increment with cutting cycle increases from 1st to 4th cutting. This report quite agreed with Diriba et al. (2014), Gashaw et al. (2015), and Walie et al. (2016) who showed the values of stand height and DMY to increase as the cutting cycle increased for the same alfalfa cultivars. Different reports indicated that the optimal harvest interval for alfalfa is between 30 tand35 days (Sheaffer, 2000). But, in the current study, longer time interval was recorded, around 57 days as compared to the bench mark indicated. This could be observed due to the difference in varieties, temperature, soil texture and management. The variation of harvesting interval might be based on a compromise between yield, quality, regrowth, and persistence (Sheaffer, 2000). But, a maximum yield on alfalfa is achieved at reproductive maturity when the nutritive value of the forage is at a minimum (Collins and Fritz, 2003).

## CONCLUSION AND RECOMMENDATION

It can be concluded that all the alfalfa cultivars had not shown any significant difference in DMY and nutritive content, but Hairy Peruvian had relatively good DMY, LTSR and higher stand height, as compared to FG-10-09(F), FG-9-09(F), Magna-801-FG(F) and Magna-788. As a result, it will be good to promote Hairy Peruvian cultivar for further demonstration and seed production.

## CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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# Vulnerability and adaptation strategies to drought and erratic rains as key extreme events: Insights from small scale farming households in mixed crop agro ecosystems of semi-arid eastern Kenya

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**Climate variability and change are some of the most pressing environmental challenges in semi-arid Kenya and Sub Saharan Africa (SSA) and are associated with persistent droughts, dry spells and erratic rains. The present study aimed at determining exposure and adaptation mechanisms among selected small-scale farmers cultivating drought tolerant crops in Wote, Makueni County, Eastern Kenya in the period 2003 to 2013. The sampled 120 farmers cultivate sorghum, cow peas and pigeon peas, which are some of the dominant multipurpose crops. Data collection methods included the use of semi-structured questionnaires. Results indicated that household level vulnerability was caused by exposure to extreme events: Drought (100%) and erratic rains (59%). Key drought adaptation means were drought resistant crops, 65%; terracing, 28%; and crop diversification, 13%. A multiple regression model, $R^2$=0.319, indicated that age, gender and land size influenced adaptation choices significantly $\rho<0.05$=0.027, 0.043 and 0.011, respectively. The results reveal prevailing exposure to extreme events at household level and further existing influence of responses by household social characteristics. From the results, the study mainly recommends adoption of alternative income activities, including on farm value addition, coupling of indigenous and modern adaptation mechanisms and provision of comprehensive climate information services.**

**Key words:** Climate change and variability, vulnerability, adaptation, smallholder farmers, semi-arid, Kenya.

## INTRODUCTION

Climate change, as defined by the IPCC, refers to "statistically significant variation in either the mean state

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of the climate or its variability, persisting for an extended period typically decades or longer" (IPCC, 2001). In addition the World Meteorological Organization (WMO) gives a wider definition of climate variability as "variations in the mean state and other statistics of climate on temporal and spatial scales beyond individual weather events" (WMO, 2015). Smit et al. (2000), in their anatomy of adaptation, relate the two phenomena by explaining the strong relationship between climate change and climate variability such that adaptation to climate change necessarily includes adaptation to variability. Climate variability and change have been identified as major challenges facing communities at local, regional and global levels in an array of ways as they lead to occurrence of droughts and floods (LVBC, 2011). These events have over time lead to sever and frequent calamities that often affect livelihoods of the already poor (Dixon et al., 2003). Key resources, such as water, are becoming scarce in the already stressed regions of sub Saharan Africa with negative implications on social and economic activities in rural and urban areas (Mongare and Chege, 2011). In many instances when there is constrained access to water households tend to spend time searching for the resource rather than engaging in productive activities. A sector that is highly vulnerable to climate variability and change is rain fed agriculture which in Africa is highly dependent on seasonal rainfall (Challinor et al., 2007; Rao et al., 2011). In Africa, such rain fed agriculture covers 97% of the crop land and is mainly practiced by rural small scale farmers who are part of the 62% of Africa's rural population (Calzadilla et al., 2009). Such numbers indicate high vulnerability to climate change impacts a situation that is worsened by non-climatic influences such as high cost of inputs and high population growth rates (Calzadilla et al., 2009; Tubiello and Fischer, 2007). Such vulnerability has been shown to directly lead to food insecurity and poverty, a situation that hampered achievement of Millennium Development Goals, MDGs (Haile, 2005) or even an impediment to the recently drafted Sustainable Development Goals, SDGs (Minang et al., 2015). These global blue prints have been widely adopted at national and subnational levels, even by development-oriented organizations. Therefore, achievement of project objectives and impact will be negatively affected by the inherent difficulty in predicting the severity of extreme events. Indeed effects of extreme events resulting from climate change are becoming a major area of concern and will affect the poor in developing countries in a wide range of ways (Desanker and Justice, 2001) including amplifying poverty levels (Speranza et al., 2010).

Climate change and variability are for example associated with drought spells as one of the key impacts. These dry spells vary in frequency and duration and are brought about by precipitation failure such that there is inadequate water to support crops and other consumptive uses (Oliver, 2005). Dry spells, in particular, occur several consecutive days during the onset of the growing season and when these last for about 40 days they graduate into a drought (Mathugama and Peiris, 2011). Associated instances of rise in temperatures and their frequency are a major limiter of crop growth, yield quantity and quality as well as an array of other crop development processes (Lin, 2011; Rao and Okwach, 2005; Rosenzweig et al., 2001; Semenov and Porter, 1995). Instances of crop failure linked to higher temperatures eventually lead to impacts such as malnutrition and even severe food shortage in extreme cases (Haile, 2005). Crop pests populations and diseases occurrence and/or virulence have also been linked to changes in temperature and humidity (Verchot et al., 2007). This phenomenon indicates that among farming communities, variation in climate will indeed be one of the drivers of crop losses due to direct and indirect impacts perpetuated by instances of variation in climatic events. Climate related events such as droughts are becoming severer and more frequent (Kisaka et al., 2015), implying many households in Semi-arid Kenya dependent on farming are becoming more impacted and their resilience highly affected. The IPCC's fifth assessment does also raise concerns that effects associated with pests, diseases on livestock and crops are likely to be a concern as the climate changes (Niang et al., 2014).

*Vigna unguculata* (Cowpeas), *Cajanus cajan* (Pigeon peas) and *Sorghum bicolor* (Sorghum) (Referred hereafter as, focus crops) are examples of drought tolerant crops and their varieties are widely cultivated by small scale farmers in the Wote area in lower eastern Kenya (RoK, 2013). These cereals constitute a key food and nutrition source in the semi-arid area and are widely cultivated in mixed crop agroecosystem. The areas climate is generally semi-arid with the southern part being mainly low-lying grassland, which is suitable for ranching. The mean temperature range is between 20.2 and 24.6°C and is characterized by extreme rainfall variability, which affects farming. Hilly areas receive about 800-1200 mm per annum while the rest of the areas receive about 500mm per annum (CSTI and MoAL, 2009). The existing community practices mainly small scale rain fed Agriculture and livestock rearing (CSTI and MoAL, 2009). The dominant soils in the study area are luvisols and cambisols (Driessen et al., 2001). Luvisols have favorable physical properties including granular surface soils that are porous and well aerated. Cambisols are characterized by a loamy or clayey soil texture with good water holding capacity and internal drainage.

Since this location is largely semi-arid, it experiences instances of climate change and variability. The area and most semi-arid eastern Kenya receives inconsistent rainfall coupled with dry spells that affect the suitability of the growing season (Kisaka et al., 2015; Speranza et al., 2010). These events could be becoming more frequent and severer even affecting the growth and development of the largely drought hardy focus crops. Since rainfall

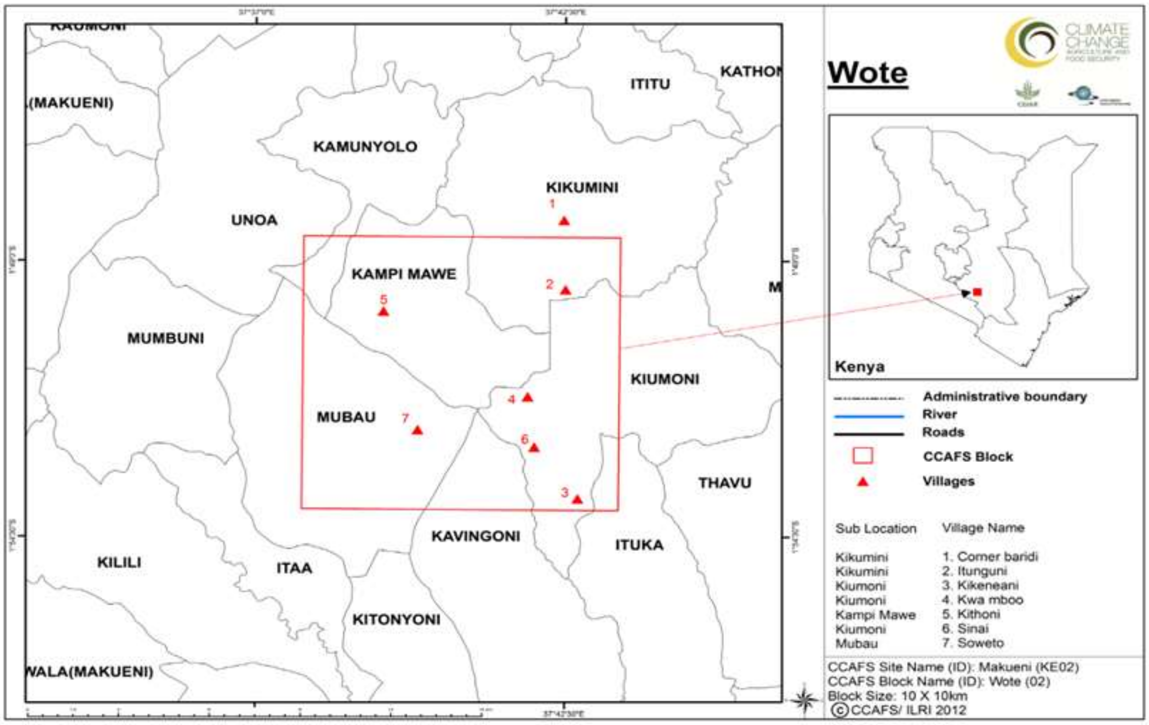


**Figure 1.** Map showing the study area.
Source: CGIAR-CCAFS (2012).

and agriculture are intimately linked, heavy reliance on rain fed agriculture as the main source of livelihood by small-scale farmers in Wote, negates development by increasing poverty when climate extremes strike. Specifically, small holder farmers in Wote are becoming increasingly vulnerable as their adaptation and resilience efforts and key livelihoods such as drought resistant crops are eroded (RoK, 2013; Speranza et al., 2010) by recurring climate impacts. The focus crops farmers were the entry point of this study since understanding climate based risks posed among these farmers is going to inform appropriate and transferable adaptive capacities. There is evidently little understanding of the vulnerability and adaptation mechanisms of such households. Accordingly, this paper characterizes the nature of vulnerability and adaptation among Wote smallholder farmers to give information on adaptation interventions for buffering against inherent and new combinations of climate extremes and associated impacts.

## DATA AND METHODS

The study was part of an ongoing project Climate change agriculture and food security (CCAFS) which cuts across the Consultative Group for International Agricultural Research (CGIAR) (CGIAR-CCAFS, 2012) (Figure 1). The project's study areas in Kenya include a 10 × 10 km$^2$ block in Wote, Makueni County (CGIAR-CCAFS, 2012). The coordinates of the specific sampling block (Figure 3) are: 37°.378 E, 1°.657 S; 37°.298 E, 1°.702 S; 37°.244 E, 1°.624S; 37°.326E, 1°.581S (Förch et al., 2011). A preceding study selected 200 households based on dominant production systems within the identified block via stratified sampling, with reference to the administrative divisions (sub-locations and villages) aided by village level leaders (Rufino et al., 2013). This study purposively sampled 120 agriculturally active and knowledgeable farmers cultivating the focus crops from the 200 households. The input of agricultural extension officers as well as local leaders such as Chiefs and Village elders came in handy.

Data collection tools included semi-structured questionnaires administered in person at household level and was conducted in August 2013. The questionnaires were developed with reference to expert knowledge and related literature and were initially pre tested. Two key household members (Main respondent and correspondent) were chosen as respondents with the aim of identifying and involving key members of the respective households. These participants were later incentivized at an acceptable rate of 1 kg of sugar at the end of the interview session. The main respondent represents the main provider of household income with the correspondent being a spouse or an elder son. The involvement of two household members is important because each contributes to the household's income, well-being and decision-making. A similar approach has been used in related studies such as Notenbaert et al. (2013a) in their work in Mozambique. In this study, responses from the main respondents and correspondents are only analyzed separately for selected variables including education and main occupation. Other variables represent the respective household responses. Collected data was entered, using CsPro and later exported to Microsoft Excel and further to SPSS. Analysis of qualitative and quantitative data was run using SPSS functions such as coding, multiple responses, descriptive statistics and multiple regression (Tabachnick and Fidell, 2001).

**Table 1.** Summary of selected Wote household characteristics.

| Parameter | Mean | SD(σ) | Minimum | Maximum |
|---|---|---|---|---|
| Household size | 6.08 | 2.38 | 2 | 17 |
| Main respondent age | 49.87 | 18.06 | 21 | 95 |
| Correspondent age | 42.63 | 16.09 | 17 | 95 |
| Farm size | 7.09 | 6.97 | 1 | 40 |

n=120.

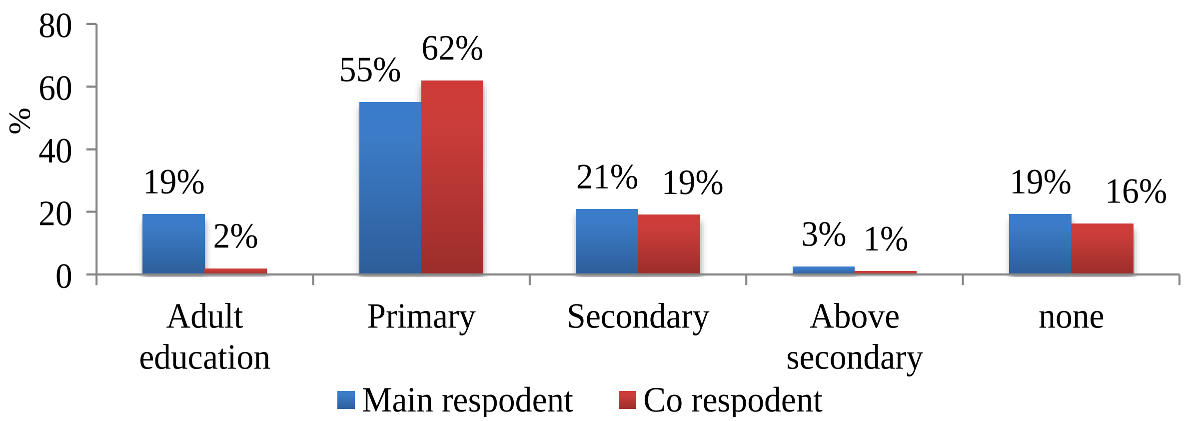


**Figure 2.** Education levels of key respondents in Wote n=120.

## RESULTS

### Socio economic characteristics

On average the households had six members which does not differ from the Kenyan national average of 5 UNFPA (2009). Further, the average land size was 7 acres with the largest recorded acreage being 40 acres, Table 1. The average age for the main respondents, regarded as household head was 49 years while that of the correspondent; usually the spouse was 42 years. Figure 2 indicates both main respondents and correspondents were mostly educated to primary level at 55% and 62% respectively.

### Key extreme events affecting households in the last ten years

Apart from climate related extremes, other effects such as crop pests and diseases play a significant role in affecting farming households in Wote over the last ten years (2003-2013) (Figure 4). It is apparent that all the households, 100%, had experienced drought. An almost equal number of households had experienced crop pests, 93% and crop diseases following at 83%. It is notable that events such as floods affect few of the households, 4.2%, and frost at 2%, indicate that the study area does indeed experience heavy rainfall related impacts. This paper pays attention to drought as the major calamity experienced by households and in the next section explore the associated impacts and instituted responses at household level.

To further bring extreme events to perspective, households were asked to rank the three major extreme events experienced with the order where a value of one represents the key calamity. The households ranking of these events were further analyzed ,using the Kendall's coefficient of concordance (Kendall's W) which is used on ordinal data and is a non-parametric statistic similar to spearman correlation (Kraska-Miller, 2013). The results shown in Table 2 indicate the ranking of key extreme events; Drought, erratic rains, pests and diseases are statistically significant ($\rho$<0.05=0.000) at 95% confidence interval with ($\chi$=32.788, Df=3). Analysis of precipitation parameters over the last 35 years by the Kenya Agricultural Productivity program (KAPP), indicates high variability and inconsistency (KAPP, 2017). Figure 5 shows instances of years with extremely high rainfall in the larger Makueni County. This represents instances of extreme rainfall that could be contributing to crop and asset losses. Most importantly, Figure 6 reveals several years with total dry spells above 40 days. This is an indicator of the inter-annual occurrence of dry conditions as extreme climate events and perhaps inherent difficulties in prediction. Such spells pose as a risk to

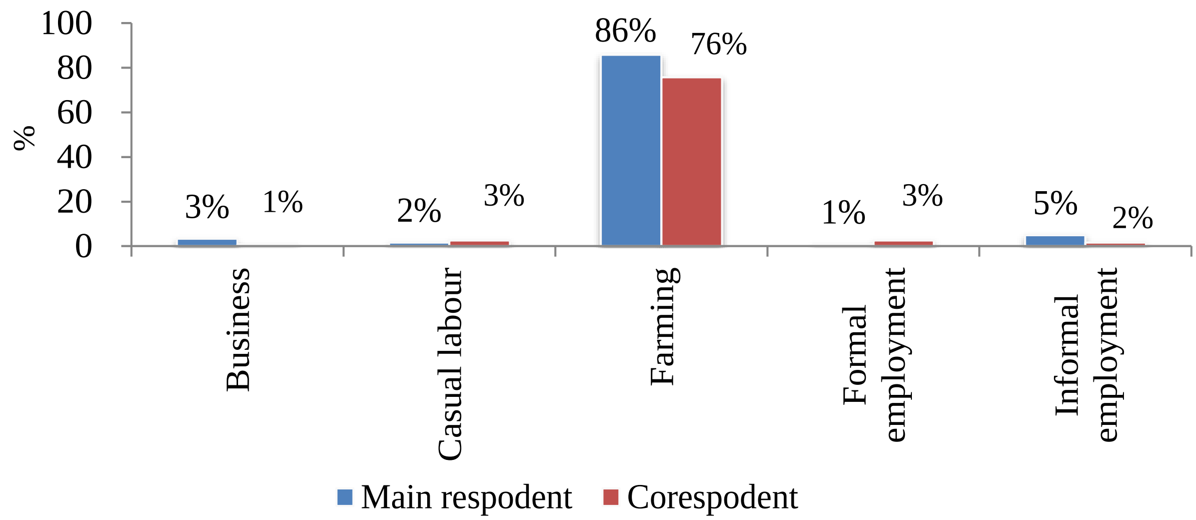


**Figure 3.** Main occupation of Respondents in Wote n=120.

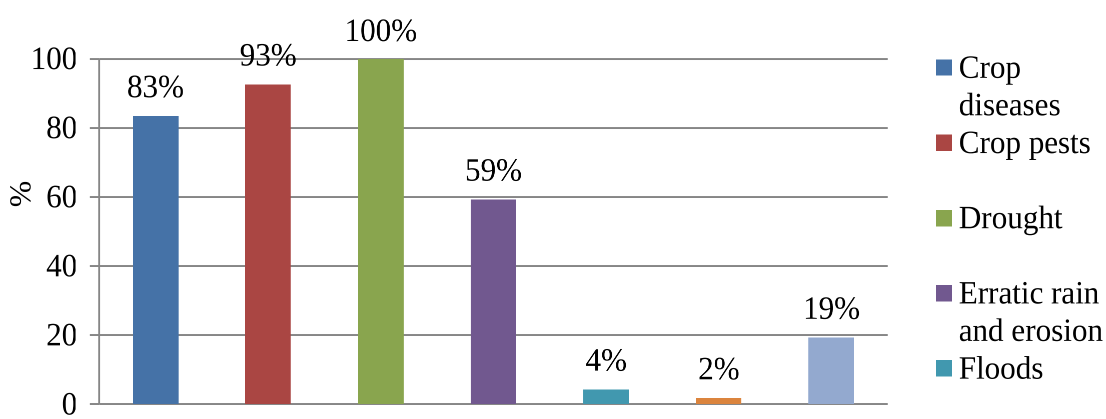


**Figure 4.** Major extreme events affecting households in Wote in the last ten years n=120.

**Table 2.** Kendall's coefficient of concordance (Kendall's W) for key extreme events as ranked by households in Wote.

| Statistic | Value |
|---|---|
| *Kendall's W* | *0.643* |
| *Chi-Square* | *32.788* |
| *Df* | *3* |
| *Asymp. Sig.* | *0.000* |
| Drought ranking | 1.06 |
| Erratic rain ranking | 2.53 |
| Crop disease ranking | 2.94 |
| Crop pest ranking | 3.47 |

farming as they contribute to massive crop failure and may cause exceeding the threshold of drought hardy

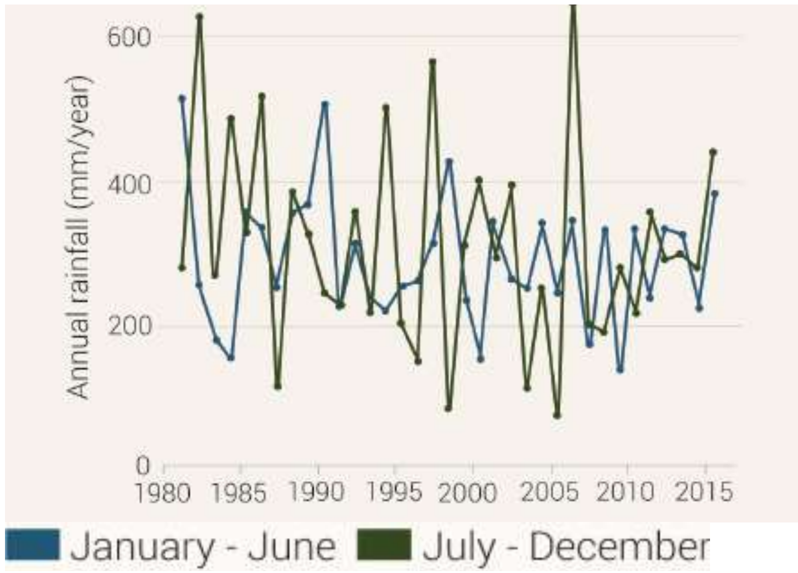


**Figure 5.** Historical annual precipitation in Makueni county.
Source: KAPP (2017).

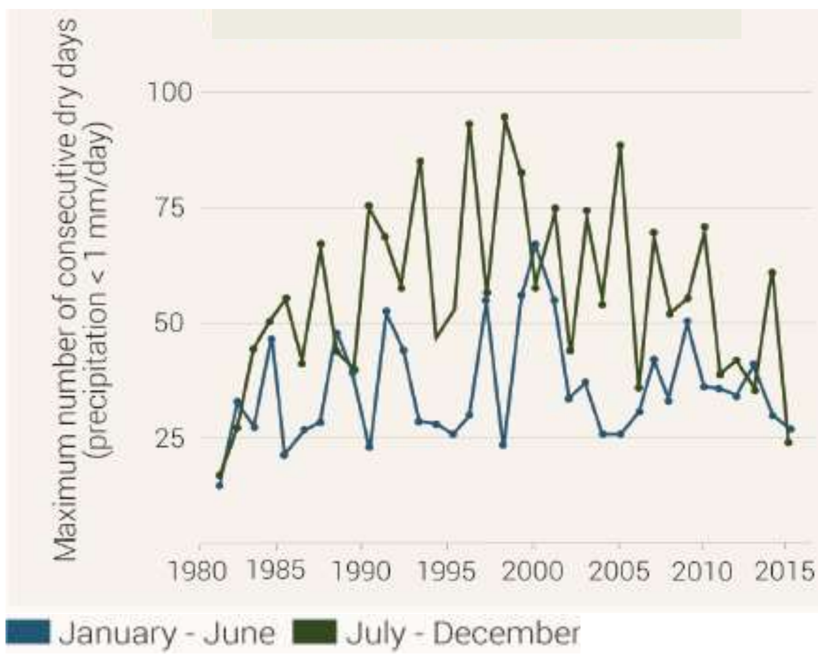


**Figure 6.** Historical distribution of dry spells in Makueni county.
Source: KAPP (2017).

cereals discussed in the next section.

### Impacts associated with drought as a key extreme event

Almost half of the households, 46%, reported that they have experienced crop failure as a result of occurrence of drought indicating risks associated with this event in the largely agriculture dependent households, Figure 7. An almost equal number, 44%, indicated that they had experienced extreme hunger in the area because of drought with an almost equal number, 43%, indicating they had experienced water shortage. These numbers

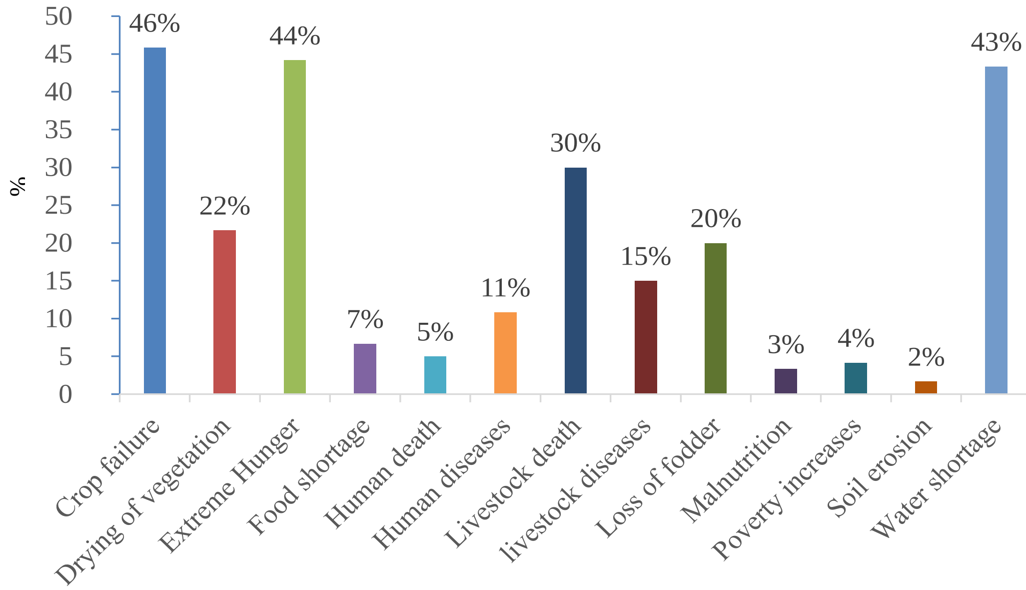


**Figure 7.** Impacts associated with drought among Wote households n=120.

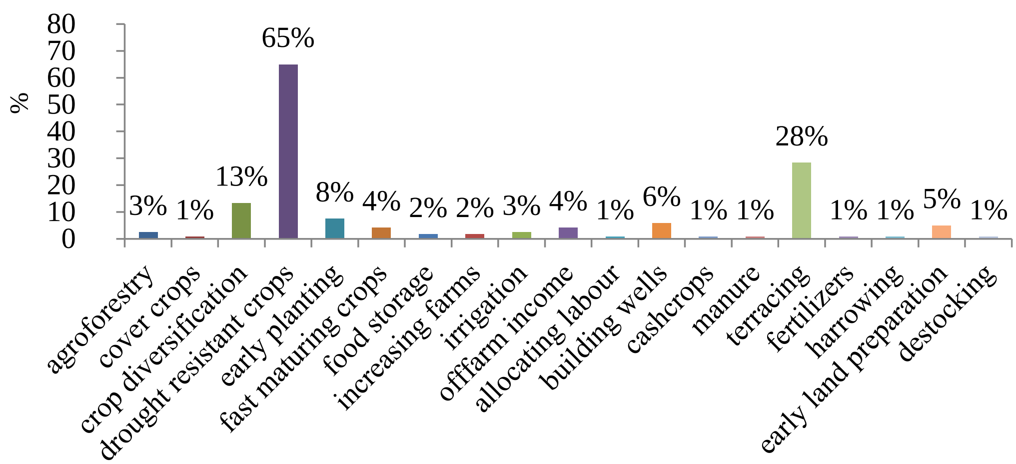


**Figure 8.** Adaptation mechanisms against drought by Wote households.

indicate that households are indeed experiencing severe effects including severe food shortage denoted as extreme hunger because of instances of drought and probable occurrence of intervening dry spells. This scenario could not only be associated with insufficiency of food but also access and variety and could be contributing to nutrition insecurity and/or malnutrition. This would largely influence growing children more who require a diet with multiple essential nutrients. Resulting to water shortage, this further worsens this situation as the deterioration of the quantity and quality of this essential commodity directly contributes to a myriad of human and livestock impacts, including health and survival. The impacts of drought, as the results show, do not only affects crops but also natural vegetation, perhaps limiting growth and distribution.

## Adaptation mechanisms

### *Adaptation mechanisms against drought*

Households engaged in an array of mechanisms to adjust to the frequent occurrences of drought with most of the key mechanisms revolving around farming (Figure 8). Most of the households, 65%, have engaged in cultivation of drought resistant crops and varieties, 13% practicing crop diversification and 28% setting up terraces all largely

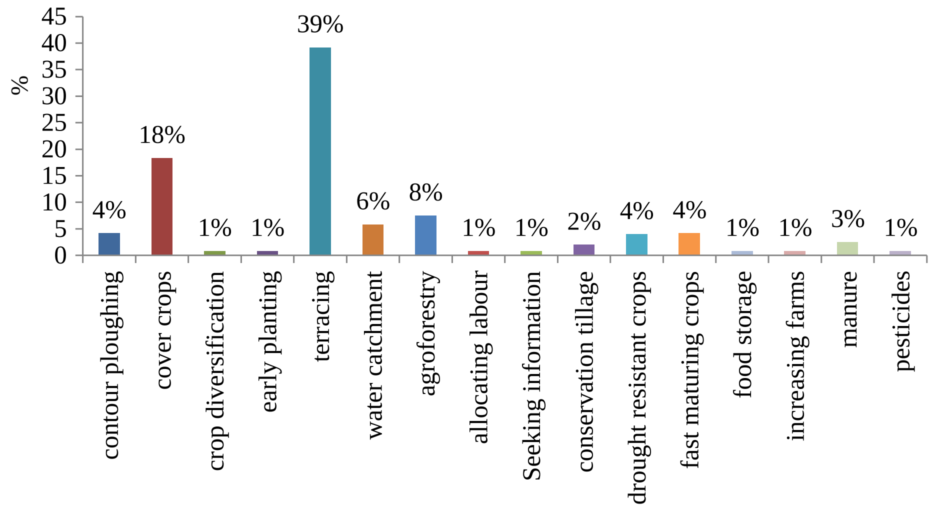


**Figure 9.** Adaptation mechanisms against erratic rains by Wote households n=120.

**Table 3.** Selected adaptation mechanisms by Wote households.

| Selected adaptation mechanism | No. | %* |
|---|---|---|
| Sale of household assets | 81 | 68 |
| Extension services | 55 | 46 |
| CBOs and farmer associations | 43 | 36 |
| Post-harvest processing and value addition | 19 | 16 |
| Credit and loans for farming | 1 | 1 |

n=120, *Percentages sum exceed 100% because these are multiple responses.

adjustments aiming at enhancing efficiency in water use.

### *Adaptations against erratic rains*

Households in Wote have made efforts to adjust to erratic rains through several response strategies. From Figure 9, most of the households, 39%, established terraces with 18% cultivating cover crops. A few households employed related mechanisms such as contour ploughing, 4%; agro forestry, 8%; and setting up of water catchment, 6%. Mechanisms of adapting to erratic rains include terracing, 39%; agroforestry, 8%; and water catchment 6%. These are principally approaches aimed at enhancing the utilization of scarce water resources.

### *Other notable response strategies*

Selected mechanisms presented in Table 3 include selected initiatives and key individual household efforts to adapt to climate extremes as well as institutional backing to enhance adaptive capacity against climate change and variability. Most of the households (68%) as Table 3 indicates, are involved in selling of household assets such as livestock. Almost half of the households (46%) accessed extension services, which aids in decisions around adaptive capacity and more so improved and new farming practices. Furthermore, 36% of the households in Wote indicated being members of Community Based Organizations (CBOs) and farmer associations. A few of the households (16%) indicated involving in post-harvest processing and value addition. This involves applying technologies that aim at improving harvests or developing multiple products from harvests or on farm produce.

### Relating adaptation mechanisms to socio economic characteristics

To understand socio economic factors influencing adaptation a multiple regression model was developed, a similar approach applied by Adebisi-Adelani and Oyesola (2013). Multiple regressions explain the overall fit of the model or rather prediction of the value of one variable from others and the relative unique contribution of each explanatory variable to the model (Tabachnick and Fidell, 2001).

**Table 4.** Descriptive Statistics of Adaptation responses against calamities by Wote Households.

| | |
|---|---|
| Mean | 4.69 |
| Median | 5.00 |
| Mode | 4 |
| Std. Deviation | 1.527 |
| Minimum | 0 |
| Maximum | 8 |

Freund et al. (2006) as well as Tabachnick and Fidell (2001) state that a multiple regression model is denoted as an extension of the linear or bivariate regression as shown in Equation 1:

$$y = A+\beta_1 x_1+\beta_2 x_2+.....................+\beta_k x_{k+}\mathrm{E},................ \quad (1)$$

Where y is the dependent, target or response variable.
A is the y intercept, the value of which is zero when all X values are zero.
X =1, 2,........., k, represent m different independent, explanatory or control variables;
$\beta_0$ is the intercept value when all predictors are 0, also denoted as $\alpha$ in other cases;
$\beta$ =1, 2,.................,m, denote the respective k regression coefficients;
$\mathrm{E}$ is the random error or disturbance term, usually assumed to be normally distributed with mean zero and variance. Also denoted as $\mu$ in other cases.

Multiple regression models require an array of assumption tests which include tests for independence of errors (residuals), linear relationship, multicollinearity, outliers and normal distribution of errors (Lund-research, 2013; Pallant, 2013). These statistical measures were used in the present study to warrant the validity of the model as well as act as a data reduction approach aiming at selection of the best predictors. In the present paper, some of the assumption tests were presented, including collinearity tests and tests for independence of errors in Table 5. Multicolinearity is examined through inspection of correlation coefficients and the tolerance or variance inflation factors (VIF) among predictors (Crown, 1998; Lund-research, 2013).A tolerance value less than 0.10 indicates high correlation with other predictors and similarly a VIF above 10 (Reciprocal of 0.1) indicates collinearity in the model (Lund-research, 2013; Pallant, 2013). From Table 5, the highest tolerance value is 0.339 (VIF=2.950) indicating the data does not exhibit multicollinearity. An important statistic as reported by Ho (2006) is the Durbin Watson statistic that ranges from 0 to 4 with a value close to zero showing strong positive correlation. The statistic is a test of the serial correlation of error values and is used to indicate non independence of error values when significant (Ho, 2006; Pallant, 2013; Tabachnick and Fidell, 2001). Ideally, the statistic should be approximately equal to two to warrant the non-assumption of the requirement. Table 5 shows there was independence of residuals, as noted by the Durbin Watson statistic of 1.684 hence the assumption was not violated. In this analysis, some continuous predictors were transformed to improve their contribution in the linear model as well as reduce collinearity.

As applied in related studies such as Adebisi-Adelani and Oyesola (2013) and Harvey et al. (2014) the Wote household's adaptation strategies were aggregated such that the total numbers of adaptations for each calamity per household were identified to form a dependent variable. The adaptation statistics are presented in Table 4. The results shown in Table 5 indicated that gender of the main respondent, in most cases the household head, significantly influences adaptation ($\rho$<0.050=0.040). Similarly the age of the key household members, the respondent and correspondent, affected the level of adaptation strategies significantly ($\rho$<0.05, =0.023=0.006) respectively. Land size as a key resource affects adaptation level significantly ($\rho$<0.05, =0.014) and more so positively ($\beta$=0.345).

## The relationship between adaptation and food insufficiency

Since food insufficiency computed on monthly basis was a key indicator of vulnerability, the relationship with the number of adaptations was further explored. This is because it is highly likely food shortage informed adaptation whether in terms of number or variety. Initially the two variables were transformed into nominal variables and the Chi-Square test used to find the relationship. The Chi-Square tests that there is a significant relationship between two categorical variables with a threshold value/significance level/$\rho$-value of 0. 05 (Huizingh, 2007). Since the Chi-Square does not specify the strength of the relationship between two variables, additional statistics were computed and in this case Cramer's V which denotes the strength of the correlation between two nominal variables(David and Sutton, 2004; Huizingh, 2007). Results in Table 6 indicate that there is a significant relationship between food shortage and adaptation strategies, $\chi^2(1)$=17.623, $\rho$=0.04. A Cramer's

**Table 5**. Summary of multiple linear regression model showing the relationship between certain household characteristics and number of adaptation responses.

| $R^2$=32.3% Durbin-Watson=1.684 | Standardized coefficients | t | Sig. | Collinearity statistics | |
|---|---|---|---|---|---|
| | Beta | | | Tolerance | VIF |
| (Constant) | | 4.895 | 0.000 | | |
| Respondent gender | -0.401 | -2.108 | 0.**040** | 0.584 | 1.712 |
| Correspondent gender | -0.323 | -1.631 | 0.109 | 0.367 | 2.723 |
| Respondent education | -0.218 | -1.448 | 0.154 | 0.445 | 2.245 |
| Correspondent education | -0.317 | -1.835 | 0.072 | 0.339 | 2.950 |
| Income sources number | 0.083 | 0.684 | 0.497 | 0.894 | 1.119 |
| Household number sqrt* | 0.185 | 1.529 | 0.132 | 0.716 | 1.398 |
| Respondent age sqrt* | -0.377 | -2.345 | **0.023** | 0.514 | 1.947 |
| Correspondent age sqrt* | -0.441 | -2.850 | **0.006** | 0.554 | 1.803 |
| Acreage sqrt[1] | 0.345 | 2.532 | **0.014** | 0.904 | 1.106 |

* Variables transformed using the square root

**Table 6**. Monthly food insufficiency statistics among Wote Households.

| | |
|---|---|
| Mean | 3.75 |
| Mode | 3 |
| Std. Deviation | 1.49 |
| Range | 7 |
| Minimum | 1 |
| Maximum | 8 |

V value of 0.227 further demonstrates this relationship as being small as per Cohen (1988).

### Vulnerability context

Food in security and /or insufficiency is a key variable in this research as a measure of vulnerability notably because the entry point of the research was drought tolerant crops cultivating farmers highly dependent on farming. This measure has indeed been applied in other vulnerability assessments for example Gabrielsson et al. (2013). In this assessment, food insufficiency was measured by the number of months that the household was experiencing difficulty in feeding themselves or rather instances of severe food shortage within a year. The statistics were present in Table 6 showing the distribution of monthly food shortage among households.

## DISCUSSION

### Socio economic characteristics

Since the study aimed at identifying exposure and adaptation to climate change, the larger number of experienced farmers as Table 1 shows, would be better at" distinguishing climate change and inter-annual variation" (Maddison, 2007) as well as exhibiting farming experience (Deressa et al., 2009). The results further show that most of the household heads had made an effort in acquiring basic education notably to the primary level. However, such minimal education is likely to reduce the capacity to adapt to extreme events and more so advancement of their livelihoods. This is because education has indeed been identified as a key avenue for gaining employment and subsequent alternative income for providing resources in rural households and is hence a key endowment to enable households deal with poverty (Christiaensen et al., 2002; Verma, 2001). The mean household size does not vary from the national average. Nevertheless, the reported average household size could play a role in determining the level of vulnerability among the households. For example, large households will benefit from distribution of on farm labour a number that can however be influenced by the age of the household members. Higher number of dependants has additionally been shown to contribute to shifting of a household from low to high vulnerability to climate change effects in other related studies since there are more mouths to feed than pair of hands to work (Leary, 2008; Nkondze et al., 2013).

The results also indicate that most of the households are largely dependent on farming as a livelihood source or are highly reliant on farm produce. However, extreme climate events effects on rain fed farming would indeed bring about significant impacts on agriculture and livestock as other studies such as Dixon et al. (2003) report. Nevertheless, a few households are engaged in alternative income generating activities such as formal and informal employment. These could act as safety nets in case of poor harvests or widespread crop failure. Such alternatives enhance access to alternative income that cushions against the effects of poverty and by extension reduces multiple risks posed by exposure to climate extremes and amplified by non-climatic influences (Adger, 1999).

## Extreme events experienced

In this study, climate change indicators reveal extreme events that households have experienced in the study area presently and over the last 30 years. These elements are also key indicators of exposure to climate change and variability against which impacts are associated (IPCC, 2001). Household ranking of all extreme events shown in Table 3 further indicates the Kendall's coefficient (W=0.643) which is close to 1 showing strong agreement or similar standards in ranking (Kraska-Miller, 2013).This can be interpreted that the households are in agreement or consensus of their rankings of key climate and related calamities risks affecting them. Drought as noted by all households has indeed been shown in related studies as a key concern. A similar observation was made by Mwang`ombe et al. (2011) in their study on rural farmers in Kenyan dry lands. Drought cases in Wote area can also be associated with the fact that the area is classified as an arid area in the category of 85-100% arid and semi-arid, with total arid and semi-arid land at 25% (RoK, 2004).
Results demonstrate that households in Wote have been affected by multiple risks as evidenced by reports of crop pests and diseases in a large number of the households. These further impact on crop health and only add to the risks posed by extreme climate events. Occurrence of such crop pests and diseases could be natural prevalence but also to certain extent interrelated and even associated with extreme climatic events. For example, Reynolds (2010) states that the relationship between pests, diseases and the environment form a 'diseases triangle' that determines the outcome of a particular crop disease. Such crop diseases and pests are likely to reduce crop yields and performance and as Reynolds (2010) adds; they are to a great extent affected by environmental factors.

Erratic rains as mentioned by more than half of the households are associated with unpredictable rainfall spells in some instances late onset of rainfall and insufficiency in the amount of rainfall and do contribute to drought and or intermittent dry spells (Vanlauwe, 2002). Such occurrence could be a great risk to hydrous stress sensitive crops such as maize particularly when such event occurs during the initial growth stages as well as development stages (Ingram et al., 2002; Kambire et al., 2010; Parry et al., 1999). This insufficiency could be due to fewer rainy days, leading to a lower volume of rainfall. In other cases, rainfall occurs in torrents such that most of the runoff is difficult to harvest and ends up as floods.

## Impacts associated with drought as a major extreme event

A non-universal description of drought, as discussed by Oliver (2005) and Paron et al. (2013), states the event as a ,natural reduction in the volume of precipitation or available freshwater for an ecosystem, over an extended length of time specifically a season or longer and such droughts differ in intensity, duration and spatial coverage. Drought is associated with certain weather timings such as season of occurrence, delays in start of the rainy season, rain versus crop growth stage as well as rainfall effectiveness (Oliver, 2005). With extreme hunger, crop failure, malnutrition and water shortage identified as key impacts associated with drought, it is likely there lay a strong relationship between occurrences of these impacts. This is because each of the effects, as some authors have noted, leads to another: severe food shortage results from crop failure, Haile (2005) while water scarcity due to rainfall failure is a key contributor in occurrence of crop failure (Dilley, 2005). These impacts are likely to have secondary effects among households in the study area. Water shortage for example, influenced by levels of precipitation and evapo-transpiration, determines the quality of available water and such water quality affects human health (Müller, 2009). Such health impacts and prevalence of malnutrition are likely to affect children and the elderly more severely (Holmberg, 2008) since they are more vulnerable when extreme events strike (Mirza, 2003).

## Adaptation strategies

The large number of households engaging in cultivation of drought resistant crops is evidence of the importance of and confidence in and reliance on crop based response strategies among households in the study area. Similar mechanisms in the face of drought have also been noted in several studies around sub Saharan Africa. These include growing of drought tolerant crops and varieties, Mwang`ombe et al. (2011); Mahu et al. (2011); Rufino et al. (2013), crop diversification, Woodfine (2009) and terracing to conserve elusive soil moisture, Mwang`ombe et al. (2011). Drought and heat tolerance cops have indeed been noted as a practical option for adaptation with appropriate implementation (Ngigi and Denning, 2009).

It is likely that households in Wote involve in crop diversification to reduce the risk of extreme events where all crops fail. This is in line with Woodfine (2009) who indicates that one of the key reasons for crop diversification other than monoculture is avoiding the risk of extremes such as droughts such that some crops are likely to survive. Agro forestry as mentioned involves growing of certain multipurpose trees and shrubs on farm to provide an array of products and services including shade, fruits, fodder, wood, carbon sequestration and wind control (Jama and Zeila, 2005; Woodfine, 2009). Among the households, this presents a useful means of accruing multiple benefits and at the same time diversifying income in the face of multiple and concurrent climate and non-climatic risks.

Erratic rains are associated with delayed onset and shorter duration or rather fewer rainy days which could be characterized by intense downpour (Simelton et al., 2011). Such erratic rains are ultimately a concern in arid and semi-arid environments since they negatively affect farming activities particularly making prediction of the start of rains or season onset difficult for farmers. Terraces as applied by most households are constructed in sloppy areas and provide an array of functions, including conservation of water and soil by slowing runoff, promoting infiltration and water storage and reducing wind erosion (Blanco-Canqui and Lal, 2008). Blanco-Canqui and Lal (2008) add that in drier areas, terraces enhance plant available water as well as groundwater recharge. To conserve the minimal moisture available, the mechanism is commonly applied in arid areas and more so in hilly landscapes (Mwang`ombe et al., 2011).

Cultivation of cover crops is widely applied in farming communities and involves cultivation of certain multipurpose legumes to manage changes in water availability (Mahu et al., 2011). Contour ploughing on the other hand aims at controlling soil erosion as a result of runoff by increasing soil water infiltration (Blanco-Canqui and Lal, 2008). As such, the aim of the mechanism is to mainly avoid effects of runoff, which leads to soil erosion while at the same time enhancing water conservation. Agro forestry as practiced by few of the households in Wote mainly aims at controlling erosion in the event of erratic rains. The practice has been documented in other studies on adaptation to erratic rains in semi-arid lands and involves planting of certain trees and shrubs along the farm edges or within crops (Mahu et al., 2011).

Crop diversification in the event of erratic rains aims at reducing the risk of losing all crops if rains fail or exhibit within season variability (Woodfine, 2009). The mechanism was noted by (Recha, 2011) in his study on adaptation strategies in semi-arid eastern Kenya.

Cultivation of drought resistant crops in the study area aims at facilitating crop survival in the event that rains fail or the amount of rain is minimal, a mechanism that is popular in semi-arid areas as noted by other studies such as (Mwang`ombe et al., 2011). Akon-Yamga et al. (2011) also found out that farmers engaged in cultivation of drought resistant varieties in a related study in Ghana and Gambia, West Africa.

Households in Wote also instituted assets sale, extension services, joining of community groups and values addition. Most households in the study area resorted to sale of assets perhaps when all response avenues are exhausted. Assets include means of production available at household level and are applied in their livelihood activities (Cooper et al., 2008). There could be a wide range of reasons that force households in extreme circumstances to opt to, sell key assets such as land and even livestock. These include paying off debts, paying school fees, purchase of inputs: a decision that reduces their chance of survival in future (Orindi and Murray, 2005). It is highly likely these reasons inform households in the study area and could have impacts on the ability to exhibit resilience in subsequent impacts. Such response involving disposal of livestock and other key assets is as a last result. Extension services include supply of information concerning improved farming practices in the face of extreme climate events and related calamities and have changed or evolved over time due to new farming needs and threats. Extension service aid farmers in Wote on decisions revolving around adaptive capacity, avoiding maladaptation and more so improved and new farming practices such as grafting and cultivation of improved crop varieties. Other studies have further indicated and demonstrated the critical role and need of extension services in; improved farming knowledge and more so their continued contribution in improving adaptive capacity in the face of climate change and variability among small scale farming households in SSA (Kabubo-Mariara and Karanja, 2007; Mustapha, 2013) as well as improvement in yields (Muyanga and Jayne, 2006).

Community based organizations (CBOs) enable households in Wote to engage in collective farming which diversifies their income. Such income enables the households to have alternative income and food sources in the event of crop failure in their individual farms. Studies have indicated additional benefits of households having membership in such CBOs. These include ease of access to loans (Hammill et al., 2008; Muyanga and Jayne, 2006) and related microfinance services provided by: governments, credit unions and SACCOs (Hammill et al., 2008). The authors add that such microfinance institutions aim to fill the gap left by traditional banks, which are unable to effectively offer such services due to barriers such as lack of collateral. They also state that some micro finance institutions do offer non-financial services such as education, training and healthcare among their members, which directly and indirectly contribute to improved household assets base, and improved farming practices. In addition to financial benefits community based organizations in Wote work towards improving individual farming practices in the face of climate variability for example by implementing shared knowledge from other farmers and more so benefiting from group capacity building by NGOs and government agencies. This vital benefit is also reported by Ngigi (2016) in their work on adaptation options for small holder farmers in East Africa.

Post-harvest processing as instituted by few households involves applying technologies that aim at improving harvests or developing multiple products from harvests or on farm produce. Examples in the Wote area include sisal processing and use of hand driven mechanical maize mills. Value addition aims at improving the shelf life, marketability and profitability of farm products or rather raise their value tremendously which improves on the income or benefits to the households. Furthermore, enterprise diversification including value addition (or processing) is a practical option to adaptation against climate change extremes (Ngigi, 2016).

**Socio economic factors and adaptation**

The results suggest that gender of the main respondent, largely the household head, influences adaptation to climate change. Perhaps this is because men, who are the household heads, play a key decision making role and even the final say towards the choice and level of investment in adaptation. Similarly the age of the key household members, the respondent and correspondent, affected the level of adaptation strategies. From the results, it can be interpreted that the older the household heads and spouses, the more likely they are to institute more adaptation strategies. This could be due to their experience with extreme events and their impacts including the ability to make decisions based on nature, frequency and extremity. Land size as a key resource affects adaptation level significantly and more so positively. This implies owning a larger land resource would increase the ability of the household to adapt probably by having a larger acreage to practice mechanisms such as crop diversification.

Other studies have identified similar and differing relationships between the selected socioeconomic characteristics and adaptation strategies. Adebisi-Adelani and Oyesola (2013) in their work in Osun state of Nigeria among selected horticultural farmers, identified similar socioeconomic factors affecting adaptation. These include age, which indicates the experience of the farmer plays a key role in determining their adaptation. A related study by Apata et al. (2009), in arable crop farmers in south west Nigeria, noted that age and land size are important factors influencing coping with climate change calamities. Deressa et al. (2009) in their work in Ethiopia similarly noted a significant relationship between selected adaptations with age and gender of the household head.Income has been identified as a key factor influencing adaptation for example, Apata et al. (2009), Adebisi-Adelani and Oyesola (2013) though in this study the influence was positive ($\beta$=.083) but not significant ($\rho$>0.05=0.497). In their work in Ethiopia, Deressa et al. (2009) noted that both on farm and non-farm income did influence certain adaptation strategies. In deed as Notenbaert et al. (2013a) report in their related work in Mozambique, availability of adequate income facilitates the households' acquisition of new varieties, irrigation technologies and other inputs as well as ability to use available information which improves their adaptive capacity. This argument applies to households in the study area as indeed economic endowment translates to the ability to invest in a wide range of response options.

The model results indicate household size does not influence adaptation significantly ($\rho$>0.05=0.132) but show a positive relationship ($\beta$=.185) a similar observation made by Adebisi-Adelani and Oyesola (2013). This direction could imply a larger household is in a position to participate in multiple and even intensive on farm duties, including working in other person's farms to supplement their income. Other studies such as Apata et al. (2009) found that household size significantly influences adaptation while in their case the relationship was negative. Large household sizes have been associated with take up of labor intensive adaptation mechanisms such as irrigation (Notenbaert et al., 2013a). Education (Number of years) did not show a significant relationship with adaptation and additionally depicted a negative correlation. Clay et al. (1998) and Anley et al. (2007) in their context however found that education and access to farmer training contribute to better adaptation. While results do not show this nature of relationship, education is a driver of household emancipation. A household is able to accrue additional income from formal employment, which is invested in multiple, or alternative response strategies. This income could also build a stronger resilience in a household.

**Vulnerability**

Social vulnerability to climate variability is a key aspect in determination of vulnerability to climate change and further should be central in interdisciplinary research as it helps solve causes rather than symptoms (Adger, 1999). An array of approaches have been applied in climate vulnerability studies such as the use of household vulnerability indexes (Notenbaert et al., 2013a) as well as reference to selected vulnerability markers including food security (Gabrielsson et al., 2013; LVBC, 2011; Recha, 2011) or specific climate extremes experienced (LVBC, 2011).

As Table 5 demonstrates, the average number of food insecure months in the study area was approximately 3

($\bar{x}$=3.75, $\sigma$=1.491) with most households experiencing 3 months food insecure months (Mo=3). The highest number of food insecure months reported was 8 with 1 as the lowest number. Such food insecurity includes the household's ability to have one meal in a day rather than at least three. This demonstrates the wider dimension of food insecurity including reliable access and affordability. Households in the study area highly ranked agricultural based income since most; 86% rely on farm produce with 50% relying on animal products as a key source of income. This distribution of income sources ,in particular reliance on rain fed farming, further demonstrates the households high risk and vulnerability from extreme events notably occurrence of drought, pests and diseases.

In an attempt to cope with extreme events farmers in the study area have instituted an array of adaptation mechanisms targeting specific calamities and land resource changes. While such array of adjustments has been instituted by households in the study area, there are underlying factors that are contributing to sensitivity and subsequent impacts associated with the key extreme events experienced notably drought. To put this argument into perspective, there is an array of factors leading to a cycle of food insecurity in the study area while households have employed adaptation mechanisms. Gabrielsson et al. (2013) argue that "when exposure, sensitivity and limited adaptive capacity reach a vantage point there is a likelihood of greater vulnerability due to destructive feedback on the human-environment system". Such limited adaptive capacity could be associated with reliance on autonomous and reactive means, with reference to experiences despite the poor performance of such means. In this regard, mechanisms such as drought resistant crops practiced repeatedly could be failed by the case of poor land fertility reported by the households. It is additionally likely that crops fail due to multiple impacts: as reported that drought, erratic rains, pests and diseases are key calamities that in other instances occur concurrently.

### Relating adaptation strategies to food shortage

Results demonstrate that food shortage as an indicator of vulnerability (Gabrielsson et al., 2013) exhibits a significant association with adaptation strategies. This relationship can be interpreted that households will tend to invest in the number and variety of adaptations based on instances and severity of food insufficiency. It is hence highly likely the greater the occurrence of food insufficiency (in number of months) at household level, the larger the number of adaptations or greater effort to respond. This effort could perhaps include a diversified approach that encompasses a variety of means not limited to crop based strategies. While the results show this relationship is small, this in no way waters down the association. The strength of the relationship whether small strongly shows among the households food insufficiency can be denoted as a key reference point when instituting adaptation strategies. Furthermore, while this association is narrow, in a large way it illuminates the importance of understanding food security in answering questions on adaptation. This includes efforts to institute sustainability at household level through climate smart practices (Nkonya et al., 2015) that enhance adaptation and minimize and eliminate poverty (Sanchez, 2000).

## CONCLUSION AND RECOMMENDATIONS

This research sought to understand the vulnerability of selected small-scale farmers through reference to selected socio economic indicators. It is apparent that the households are mainly agriculturalists, heavily dependent on rain fed agriculture. As pertains exposure to extreme events, it has been found out that drought is the main climate related calamity affecting households in the study area. The study also reveals that exposure to such climate related events, has resulted into several impacts.

The study indicates that the key effect, drought, has been associated with crop failure, food shortage, water shortage as well as effects on livestock and human health. In the face of such climate change and variability impacts, households in the study area have devised an array of indigenous and modern adaptation mechanisms. The study concludes by outlining the evident sensitivity and vulnerability of the households with reference to the key occupations and income source such as farming. At the same time, experienced extreme events and associated impacts mainly food insufficiency are highlighted as indicators of vulnerability.

Enhancement of adaptive capacity among Wote small-scale farmers cultivating the drought tolerant focus crops is necessary to enhance sustainable development at the local level. The findings demonstrate appropriate and informed resilient crop based adaptation mechanisms have a high potential in assisting small scale farmers achieve food, income and livelihood security. The existing association between food shortage and adaptation strategies underpins this importance.

Based on these findings and literature, the study recommends the following actions to reduce household's vulnerability. These are replicable and relevant to smallholder farming systems in semi-arid areas of SSA that experience climatic extreme events such as erratic rains, dry spells and drought. First, action can be taken to scale up locally made and or homegrown technologies and innovations employed by smallholder households to reduce their sensitivity to extreme events. This is because high potential adaptation mechanisms will be informed by local perceptions and more so, manifestations with climate change and variability. Secondly, there is need to enhance adoption of alternative ecologically friendly income sources, for example non-on farm income generating activities and at the same time exploring benefits of value addition and/or on farm processing. Thirdly, the study recommends that households could join community groups to enhance access to community-based loans and other benefits such as improved farming practices. Another approach is provision of climate innovation services such as the use of mobile phone platforms to urgently inform small holder farmers on impeding dry spells prior to planting. Lastly, the study recommends further research including alternative approaches to vulnerability assessment such as utilization of quantitative household composite vulnerability indexes, the use of recent vulnerability methodologies proposed by the IPCC and incorporation of land use and cover change analysis as well as climate scenarios to project future effects on crops and landscapes. Another interesting research would be exploring the nexus between food-water and energy access at the household level.

## CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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