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Full Length Research

Laboratory evaluation of some botanicals and fermented cow urine against *Chilo partellus* (Swinhoe) (Lepidoptera: Crambidae)

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Chilo partellus **(Swinhoe) is the most important destructive pest of sorghum in Africa which results in complete crop loss. Currently the management strategies rely heavily on chemical insecticides, which do not provide effective control. The uses of bio-pesticides are encouraging over chemical pesticides. The study was carried out to identify effective plant and animal products and optimum concentrations against** ***C. partellus*****. 7 treatments each at 3 concentrations (2.0, 2.5 and 3.0 g and 1.0, 1.5 and 2.0 ml) were applied on 2nd and/or 3rd instars larvae. The untreated check was used for comparison. The experiment was laid out in a completely randomized design with 3 replications for each concentration. Result revealed among the treatments** ***Milletia ferruginea*** **Hochst seed powder and aqua extract caused the highest (100%) mortality at 3 g and 2.0 ml concentration on the 2nd day. Cow urine and the mixture (*****M. ferruginea*****+cow urine) were recorded higher efficacy mean mortality (86.7 and 93.3%) at 3.0 ml concentration within 3 days respectively.** ***Phytolacca dodecandra*** **L. seed powder, aqua extract and the mixture (*****P. dodecandra*****+cow urine) showed significantly lower efficacy mean mortality. In conclusion,** ***M. ferruginea*** **powder and aqua extract, cow urine and combination of** ***M. ferruginea*** **with cow urine were identified as good alternatives to chemical pesticides against** ***C. partellus.***

Key words: *Chilo partellus*, cow urine, *Milletia ferruginea*, *Phytolacca dodecandra,* sorghum.

INTRODUCTION

Chilo partellus (Swinhoe) (Lepidoptera: Crambidae) is considered to be the most important pest of sorghum in sub-Saharan Africa including Ethiopia (Damte and Chichaybelu, 2002; Tesfaye and Gautam, 2003). Application of chemical insecticides has been recommended to protect sorghum from *C. partellus* attack. However, chemicals are too expensive and are the cause of environmental and health hazards if not used judiciously (Gupta et al., 2010). Pesticide that have a sub-lethal toxicity to target pests, but still kill natural enemies of the pests may cause target pests to increase, resulting in even higher yield losses (Islam et al., 2013;

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Table 1. Treatments used in the management *of C. partellus* on sorghum.

S/N	Treatment	Common/local name	Concentration		
			Day 1	Day 2	Day 3
1	*M. ferruginea* powder	Birbira	1.0 mg	1.5 mg	2.0 mg
2	*P. dodecandra* powder	Endode	1.0 mg	1.5 mg	2.0 mg
3	*M. ferruginea* aqua extract	-	1.0 ml	1.5 ml	2.0 ml
4	*P. dodecandra* aqua extract	-	1.0 ml	1.5 ml	2.0 ml
5	Fermented cow urine	Cow urine	1.0 ml	1.5 ml	2.0 ml
6	*M. ferruginea* aqua extract + FCU	-	1.0 ml	1.5 ml	2.0 ml
7	*P. dodecandra* aqua extract + FCU	-	1.0 ml	1.5 ml	2.0 ml
8	Control (untreated check)	-	-	-	-

FCU- fermented cow urine.

Khan et al., 2015). So these facts brought the need for search alternative pest control options, especially those that are cost effective and environmentally friendly.

The use of plant and animal-based insecticides increases from time to time not only due to their availability but also their simplicity to prepare and increase quality of the crop in taste (Getu et al., 2008; Kareru et al., 2013). They are not phytotoxic, easy to grow, cause no hazard to non-target organisms, wild life, humans or the environment (Islam et al., 2013; Tilahun and Azerefegne, 2013). In most cases their bioactive compounds are fairly complex groups; thereby making it more difficult for the pest to develop resistance (Wahedi et al., 2016). However, there is no or less study carried out, or documented report regarding plant and animal-based insecticides efficacy test for managing *C. partellus*. Therefore, screening the effective plant and animal-based insecticides is crucial against this pest. Thus, this study was conducted to determine the efficacy of specific plant and animals-based insecticides and determine the best product that controls *C. partellus*.

MATERIALS AND METHODS

The study was conducted at Kombolcha Plant Health Clinic, Ethiopia, under ambient laboratory conditions in 2016/17. Eggs were collected from field 1 to 3 weeks after plants emergence. After 5 to 11 days, the newly hatched larvae were reared in a 600 ml rearing plastic beakers the top of which was covered with nylon mesh. Larvae were supplied pesticide free fresh sorghum leaves and stems. Seeds of *M. ferruginea* Birbira and *P. dodecandra* Endod were collected from Addis Ababa University, Arat-kilo Campus and road sides grown voluntarily plantations at Dessie town, Ethiopia. Cow urine was collected from the local dairy farm in the morning into a plastic container. Seeds were washed, dried and grounded into fine powder manually using home-made mortar and pestle (Jembere, 2002). The powder was kept separately in packed plastic bags in a refrigerator at 4°C until needed for its crude extractions. Each sample of 50 gm powder was weighed separately and mixed with 100 ml water in a separate flask for crude extractions (Venkat et al., 2012). The mixtures were stirred for 15 min using a magnetic stirrer until homogenous solutions was formed and then left to stand. Each mixture was filtered through double folds Muslin cloth. After evaporating the solvent the solid extract was then used to prepare the serial dilutions. Each serial concentration was prepared by dissolving 100, 150 and 200 mg of each fine powder with 100 ml of distilled water (that is, to form 1, 1.5 and 2 ml concentrations) levels respectively. Cow urine was left 6$\pm$1 days in the shade at room temperature for fermentation; it was sieved and diluted with water at the ratio of 1:3 (v/v) (Verena, 2007). Treatment combinations were prepared by mixing equal volumes of cow urine with equal volume of each extracts. Treatments were applied on the 10, 2nd and/or 3rd instars larvae per Petri dish, and preserved food with pieces of sorghum stalk. Water was used as a control and all treatments were compared with the untreated check. All treatments each at 3 concentrations levels were laid out in a complete randomized design (CRD) with 3 replications for each concentration (Table 1). The numbers of larvae were recorded before spray and every 24 h after treatment applications till 3 days.

Data analysis

Data were subjected to analysis of variance (ANOVA) and significant means were separated by Least Significant Difference (LSD) at 0.05 level, using SAS program version 9.1 (SAS, 2009).

RESULTS

The effect of biopesticides on larval mortality of *C. partellus* after 1 day of treatment application

Effect of bio-pesticides on larvae of *C. partellus* showed that in all the rates, significant (P<0.05) differences were found among the treatments (Table 2). After 1-day treatment application, about 0.3 to 86.6% mortality was observed due to application of different bio-pesticide when compared to untreated control (0.3%). All treatments caused rate dependent mortality. The highest percent (86.6%) larval mortality was recorded on *M. ferruginea* aqua extract at the higher (2.0 ml) rate and the lowest percent (0.3%) mortality was observed at the lower (2 g and 1 ml) rates of *P. dodecandra* powder, aqua extract and cow urine + *P. dodecandra* respectively, however mortality at these treatments was not

Table 2. Mean percentage (±SE) of cumulative mortality of *C. partellus* larvae at different application rates of bio-insecticides.

Botanical	1 day after treatment application		
	Rates (g) and ml/lt		
Powder (g)	**2.0**	**2.5**	**3.0**
M. furrgunea powder	33.3±8.8[Cab]	53.3±3.3[Bab]	73.3±3.3[Abc]
P. dodecandra powder	0.3±0.3[Cf]	16.6±3.3[Bcd]	26.6±3.3[Bef]
Aqua extracts and mixtures (ml)	**1.0**	**1.5**	**2.0**
M. ferruginea aqua extracts	26.6±12.0[Dbc]	53.3±8.8[Cab]	86.6±3.3[Bac]
P. dodecandra aqua extracts	0.3±0.3[Cf]	16.6±6.6[Acd]	20.0±5.7[Afg]
Cow urine	16.6±6.6[Dcd]	30.0±5.7[Cb]	50.0±5.7[Bde]
Cow urine + *M. ferruginea*	13.3±3.3[Dde]	26.6±0.3[Bbc]	56.6±8.8[Abd]
Cow urine + *P.dodecandra*	0.3±0.3[Cf]	20.0±5.7[Bcd]	26.6±8.8[Aef]
Control (Untreated check)	***0.3±0.3***[Af]	***0.3±0.3***[Af]	***0.3±0.3***[Af]
SE±	***4.2***	***4.2***	***4.2***
CV (%)	7.8	7.8	7.8
LSD at 0.05	12.2	12.2	12.2

Means followed by upper letter across row and lower letter within column are not significantly different at 5% level, LSD.

statistically different from the control.

The effect of biopesticides on larval mortality of *C. partellus* after 2 days of treatment application

Data on the mortality of the 2nd and 3rd instar larvae of *C. partellus* showed that all the treatments were highly significant (P<0.05) and superior over the control after 2 days treatment application (Table 3). All botanical treatments showed significantly (p< higher mortality) at the 2nd days of exposure time compared to the control. The highest larval (100%) mortality was recorded on *M. ferruginea* powder and aqua extract at the higher (3 g) rate. Mortality at this rate was not statistically different from 2.5 g powder. The highest larval mortality recorded for *M. ferruginea* aqua extract was at 2.0 ml. *P. dodecandra* aqua extracts caused significantly lower (20.3%) mortality at the lower (1.0 ml) rate of application (Table 3).

The effect of biopesticides on larval mortality of *C. partellus* after 3 days of treatment application

Significant lethal effects of all the treatments on *C. partellus* larvae were found 3 days after treatment compared with the control. Mortality was increased as the rate of the extract applied increased in concentration. All botanical treatments showed significantly (p< higher mortality) at 3 days of exposure time compared to the control. The highest (100%) larval mortality was recorded on *M. furrgunea* powder and aqua extract at the higher rates. Mortality at the lower rates was not statistically different from the higher rates applications. The other treatments showed the highest larval mortality at the higher rates of applications. The lowest (26.6%) mortality was recorded in aqua extracts of *P. dodecandra* at the rate of 1.0 ml (Table 4).

DISCUSSION

Result of the laboratory experiment indicated that all treatments significantly resulted in *C. partellus* larval mortality compared to the untreated check. These results are in agreement with previous work of Shiberu et al. (2013) who reported that botanical products like water extracts of Birbira, Endode, Neem and Pyrethrum gave good control of Termites pests.

There were high significant (P<0.01) difference among treatments in laboratory after exposure of 72 h. Among all the treatments used *M. ferruginea* powder and aqua extract were found to be the most toxic and caused the highest (86.67-100%) mortality within 48 h at the higher rate of applications. *M. ferruginea* seeds powder and aqua extract have been reported to have insecticidal properties. For example, *M. ferruginea* seed powder extracts resulted in a 96% mortality rate of maize weevils, *Sitophillus zeamais* 72 days after treatment application (Jembere, 2002).

The toxicity of the plant can be attributed to rotenone which is one of the dominant compounds found in the seed and stem bark of *M. ferruginea* and is a well-known botanical insecticide through contact and stomach poisoning (Gupta et al., 2010). Damte and Chichaybelu (2002) also tested the toxicity of Milletia seed against Adzuki bean beetle, *Callsobruchus chinunesis* and found that it gave complete protection of stored chickpea for six months in the laboratory.

Table 3. Mean percentage (±SE) of cumulative mortality of *C. partellus* larvae at different application rates of bio-insecticides.

Botanical	2 days after treatment application		
	Rates (g) and ml/lt		
Powders (g)	**2.0**	**2.5**	**3.0**
M. furrgunea powder	70.0±5.7^{Ca}	86.6±3.3^{Ab}	100.0±0.0^{Aa}
P. dodecandra powder	50.0±5.7^{Cac}	56.6±8.8^{Bc}	60.0±11.5^{Ab}
Aqua extracts and mixtures (ml)	**1.0**	**1.5**	**2.0**
M. ferruginea aqua extracts	53.3±8.8^{Dab}	66.6±3.3^{Cbc}	100.0±0.0^{Ba}
P. dodecandra aqua extracts	20.3±5.4^{Dcd}	23.3±3.3^{De}	36.6±12.0^{Cd}
Cow urine	33.3±8.8^{Fbc}	56.6±3.3^{Ec}	63.3±8.8^{Dab}
Cow urine + *M. ferruginea*	33.3±6.6^{Dbc}	50.0±10.0^{Cd}	63.3±3.3^{Bab}
Cow urine + *P. dodecandra*	23.3±0.3^{Bbc}	26.6±6.6^{Bde}	43.3±8.8^{Ac}
Control (Untreated check)	3.3±0.8^{Af}	3.3±0.8^{Af}	3.3±0.8^{Af}
SE±	5.1	5.1	5.1
CV (%)	9.4	9.4	9.4
LSD at 0.05	13.7	13.7	13.7

Means followed by upper letter across row and lower letter within column are not significantly different at 5% level, LSD.

Table 4. Mean percentage (±SE) of cumulative mortality of *C. partellus* larvae at different application rates of bio-insecticides.

Botanical	3 days after treatment application		
	Rates (g) and ml/lt		
Powders (g)	**2.0**	**2.5**	**3.0**
M. furrgunea powder	83.3±6.6^{Ba}	93.6±3.1^{Abc}	100.0±0.0^{Ab}
P. dodecandra powder	53.3±3.3^{Ddc}	56.6±8.8^{Ce}	73.3±5.7^{Bcd}
Aqua extracts and mixtures (ml)	**1.0**	**1.5**	**2.0**
M. ferruginea aqua extracts	80.0±5.7^{Bb}	90.0±5.7^{Ac}	100.0±0.0^{Ab}
P. dodecandra aqua extracts	26.6±3.3^{Def}	46.6±8.8^{Cde}	53.3±3.3^{Bde}
Cow urine	53.3±5.7^{Ddc}	56.6±3.3^{Ce}	86.6±6.6^{Bc}
Cow urine + *M. ferruginea*	60.0±5.7^{Dc}	70.0±5.7^{Cd}	93.3±3.3^{Ab}
Cow urine + *P. dodecandra*	46.6±12.0^{De}	43.3±8.8^{Cdf}	60.0±11.5^{Bd}
Control (Untreated check)	3.3±0.8^{Ef}	3.3±0.8^{Ef}	3.3±0.8^{Ef}
SE±	5.4	5.4	5.4
CV (%)	14.5	14.5	14.5
LSD at 0.05	11.5	11.5	11.5

Means followed by upper letter across row and lower letter within column are not significantly different at 5% level, LSD.

Laboratory study on the toxicity of cow urine against *C. partellus* larvae caused high mortality (86.67%) as compared to the control. Similar result was reported in India by Tesfaye and Gautam (2003) who reported that cow urine caused 80% mortality of Welo bush cricket (WBC), *Decticoides brevipennis* (Raggea) in 12 h after treatment and reached 90% after 24 h and was at par with neem leaf extract. They also reported 79.6% *Drosophila melanogaster* (Meigen) mortality as compared with 2.8% in control and it was at least 3 times more effective than neem. Effect of the mixture (*M. ferruginea* aqua extract and fermented cow urine) was not significantly different from *M. ferruginea* powder and aqua extract (93.0%) at the higher rate of application, 2.0 ml after 72 h. Powder and aqua extracted of *M. ferruginea* caused significant larval mortality followed by the mixture (*M. ferruginea* aqua extract and fermented cow urine) at the lower rates. The other treatments show larval mortality at the higher rates of applications. This showed that from the different treatments used powder and aqua extracts of *M. ferruginea* found to be the most effective as compared to all other treatments.

High mortality due to *M. ferruginea* when compared to other plant products could be attributed to the presence of bioactive and other bitter compounds responsible for anti-feeding activity that result in the starvation and death of insects. Comparison of this result with previous work has shown consistency with Jembere et al. (2002) where water extracts of *M. ferruginea* caused higher toxicity to all the castes of termites in which 93 to 100% mortality was recorded at all concentration levels. *M. ferruginea* powder and seed kernel aqua extracts have been reported to be effective against various species of insects and are considered safe for human health and environments (Jembere, 2002; Muzeyi and Jembere, 2005; Taddese et al., 2010).

In contrast, *P. dodecandra* aqua extract and the mixture (*P. dodecandra* and fermented cow urine) were least active as compared with the other treatments. Significant lethal effects of the treatments on larvae of *C. partellus* were found three days after treatment applications compared with the control. The assumption for this may be that the active compounds present in these treatments were less in amount. However, larval mortality due to these treatments was observed to increase as the exposure time of the pest to the treatment increased. As exposure time extends there was a progressive increase in the toxicity of these treatments to the test insect registering appreciable mortality of *C. partellus* larvae.

The present result clearly showed that *P. dodecandra* aqua extract and the mixture (*P. dodecandra* and cow urine) required three days to kill 53.3 and 60.0% of *C. partellus*. This implied mortality increases due to these treatments at the higher rates. Hence the days to higher larval mortality took significantly longer periods and required higher rates of applications. The probable assumption might be due to the slow acting effect of the potent insecticides present in these treatments. Comparison of this result with previous work has shown consistency to Shiberu (10) who reported that mortality of *B. fusca* increases at the concentrations of the treatments and exposure time of the insect increases.

Thus these treatments are less effective against *C. partellus* larvae compared to other treatments tested within three days, however they were considered as moderately effective treatments on *C. partellus* control. *C. partellus* is an internal feeder and when the larvae grow to be mature normally develops successfully inside the stem. Therefore, botanical extracts and fermented cow urine as a traditional pest control will completely increase the mortality rate of spotted stem borer, *C. partellus* when applied in the early stages of this pest.

Conclusion

The study concluded that many of the treatments tested appear to be quite effective as local source of insecticides. The efficacy of these treatments varied with different concentrations, time intervals and length of exposure time. However, all the treatments tested showed significant insecticidal property against *C. partellus*. Out of the 7 treatments tested, *M. ferruginea* powder and aqua extracts were having acute toxicity. *P. dodecandra* powder, cow urine and the mixture of *M. ferruginea* aqua extract with fermented cow urine were observed to relatively had high insecticidal activity. *P. dodecandra* aqua extract and its combination with cow urine were observed to have low insecticidal activity. Therefore, from the current study powder and aqua extract of *M. ferruginea*, cow urine and combination of *M. ferruginea* aqua extract with cow urine are identified as good alternatives to chemical pesticides in controlling *C. partellus*. However, further study is needed on this regard to confirm the efficacy of these plant and animal-based insecticides and their practical effectiveness under natural conditions against *C. partellus* without any side effects on none target organisms and the environment.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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Full Length Research

Assessing the impacts of climate change and variability on maize post-harvest system at Kongwa and Kondoa District in Tanzania

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This study attempted to investigate the pattern and trend of climate change, its influence and interaction with maize post-harvest system and established the current status of maize post-harvest losses at Kongwa and Kondoa district in Tanzania. Participatory rural appraisal technique and household survey methods were used to collect primary data. Secondary data for the study area including rainfall and temperature data from the year 1982 -2017 were collected from Tanzania Meteorological Agency. Qualitative data were analyzed thematically using Nvivo software. Quantitative data from household survey were cross tabulated using SPSS software version 20 and the results were confirmed using canonical correlation test while pattern and trend of rainfall and temperature data were analyzed using trend lines and was confirmed using Mann-Kendall trend test. Findings indicated that annual temperature increase and monthly rainfall pattern changes influences maize post-harvest losses with significant losses denoted more during harvesting and storage with a positive correlation of R^2= 0.014 and R^2 = 0.121 respectively, while statuses for the maize post-harvest losses are below the threshold value of 40%. The study recommends increased awareness among farmers through trainings on climate change adaption and mitigation practices to reduce fungal growth on maize whose growth is favored by rainfall and temperature variations.

Key words: Temperature, rainfall and food losses.

INTRODUCTION

Impacts of climate change have been raising concerns worldwide about the potential changes to food security particularly to developing countries who depend on rain fed agriculture (Adams et al., 1990; Ahmed and Stepp, 2016; Toit et al., 2011). Climate change impacts such as prolonged droughts, extreme temperatures, varied rainfall patterns have caused reduction in the number of reliable crop growing days, eruption of climate related pest and diseases and reduction of soil moisture in arable land (Peiris et al., 1996; Joshi et al., 2011). Such impacts have altered potential crop yield through short term crop failures and long term production declines (FAO et al., 2017), hence increasing vulnerabilities to smallholder farmers in developing countries (Wheeler and von Braun,

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2013). As a result, global effort on addressing climate change and variability impacts on food security was focused mainly on improving and increasing crop production (Mendelsohn and Dinar, 1999; Morton, 2007). As a result, this has given rise to technological advancement such as the generation and adoption of improved seeds varieties, irrigation systems and soil conservation practices as means for crop adaptations towards climate change and variability impacts (Lobell et al., 2008). It was expected that increasing crop resilience and adaptation would increase crop production and cause reduced food insecurity conditions. However, despite the efforts food insecurity conditions still prevails particularly in developing nations. There has been a substantial increase in the number of hungry people in developing nations from 169 million in 1990 to 239 million in 2010 (UN, 2011). Among the developing nations, Africa is reported to have the highest percentage of undernourished people in the world and in 2050 the number of hungry people in Africa is expected to increase to 1.7 billion (FAO, 2009). In Tanzania, it is estimated that the condition of food insecurity still prevails in 730,000 rural households in the semi-arid areas (WFP, 2013).

This study argues that a resilient crop production system alone without a resilient post-harvest system cannot address the existing food insecurity conditions particularly in the rural households of the developing nations (MAFSC, 2009). Global status of post-harvest losses indicates that about 1.3 billion tons of foods are wasted and lost annually (FAO, 2011). In developing nations nearly 65% of losses occurs from production to post-harvest stages while in developed nation food losses often occurs at the retail and consumer end of the supply chain (CTA, 2012). In sub- Saharan countries, it is estimated that 50% of fruits and vegetables, 40% of roots and tubers and 20% of cereals are lost before reaching the market (Daminger et al., 2016). In east Africa post-harvest losses are high in cereal crops such as maize *(Zea mays)*, rice (*Oryza sativa*), sorghum (*Sorghum bicolor*), groundnuts (*Arachis hypogaea*) pulse (*Phaseolus vulgaris)*, cassava (*Manihot esculenta)* and sweet potatoes (*Ipomoea batata)*. In Tanzania, status of food losses have shown that 15-40% of cereal crops are lost annually (Cranfield et al., 2007; Ivanic and Martin, 2008). These huge volumes of food losses occurring along the post-harvest system control the future prosperity of food security (Spurgeon, 1976). Apart from food losses, time, labor and resources are also lost, it is reported that food loss in Africa has caused 470 million smallholder farmers to suffer from 15% declined income, while 25% of freshwater and 20% of land get wasted on unconsumed food (FAO, 2017). These figures are alarming and calls for immediate solutions.

Although there are numerous factors that contributes to post harvest losses including poor handling and storage, Suleiman and Rosentrater (2015) and Abass et al. (2013) indicate that climate change influences the 40% of the annual cereal crop losses. Most studies including (Chegere, 2018; Olayemi, 2016; Kramer, 1977; Kitinoja, 2013; Babatola et al., 2008) have related temperature changes to have a direct influence on food losses during storage although the post-harvest system comprises of more than one stage. The ultimate questions this study impose is that how and to what extent does climate change and variability influence food losses across the rest of the stages in the post-harvest system besides storage stage. It is on this ground that this study intends to provide a comprehensive analysis of the climate induced food losses across the post-harvest system. Specifically, this study aims at understanding the pattern and trend of climate change and variability, investigating the influence and interaction of climate change and variability with maize post-harvest losses and establishing of the extent and current status of post-harvest losses. This information is important for effective resilience building of post-harvest system for improved food security.

Conceptual framework

The conceptual framework guiding this study was adopted and modified from McNamara and Tata (2015) on principles of designing and implementing agriculture extension programs for reducing post-harvest losses (Figure 1). According to McNamara and Tata (2015), efforts to address food loss should begin from production to post-harvest system. There are numerous factors that contribute to food losses across pre and post-harvest system such as poor handling, lack of technology and climate change impacts. The influence of climate change impacts towards food losses begins by lowering potential yield during crop production that is pre harvest losses and further reduces the attained yield through post-harvest losses particualry in the storage as indicated by (Chegere, 2018; Olayemi, 2016; Kramer, 1977; Kitinoja, 2013; Babatola et al., 2008). Hence, presence of both resilient pre harvest system and post-harvest system ensures stable household food security, such that lack of either contributes more to the problem of household food insecurity conditions. This study modifies the framework by arguing that each stage of the post-harvest system is directly exposed to climate change impacts hence influencing major food losses before consumption, and thus contributing to increased household food insecurity condition. It is therefore important to consider climate change and variability impacts in the whole post-harvest system rather than storage alone for improved food security conditions at the households.

METHODOLOGY

Location and characteristic features of the study area

This study was conducted at Kongwa and Kondoa districts in Dodoma region; the region lies at latitude 5°48′57.60″ South,

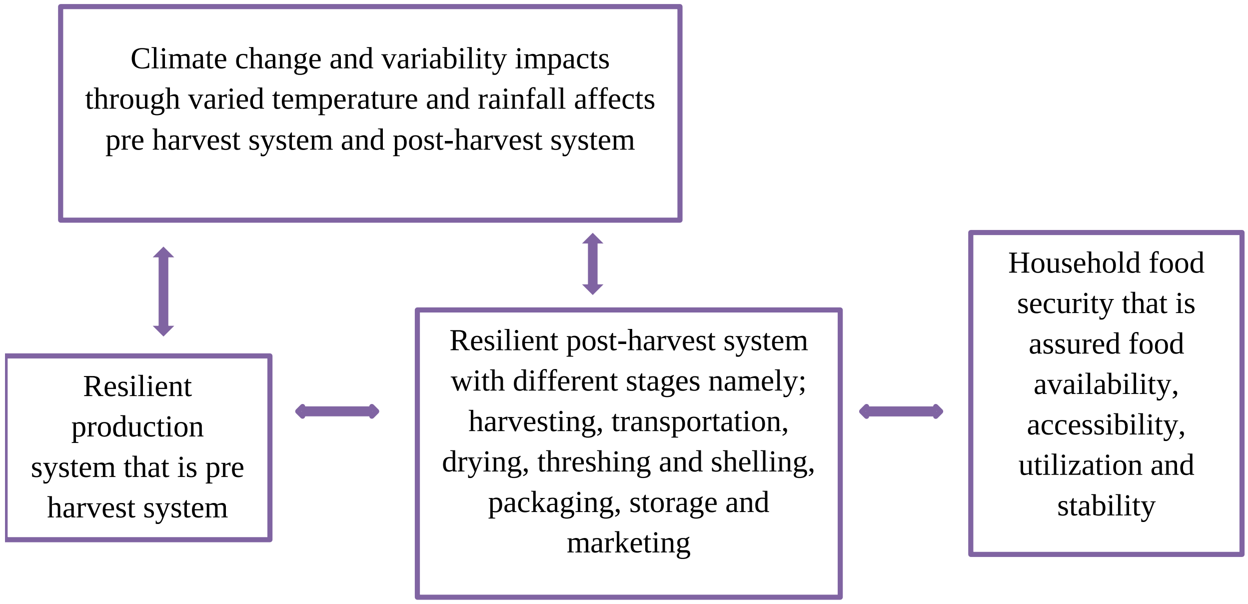

Figure 1. Climate Induced Food Loss along the Pre and Post-Harvest System.
Source: Adopted and Modified from McNamara and Tata (2015).

longitude 36°02′49.20″ East (URT, 2013). The selection of study area was based on the presence of semi-aridity climatic features, presence of maize crop production (focus crop of the study) and occurrence of food losses across the post-harvest system. It is reported that a total of 45,098 and 81,069 households grow maize in Kongwa and Kondoa district respectively (URT, 2003). Three villages were purposively selected from Kondoa district namely; Bumbuta, Bukulu and Salanka while in Kongwa district, Mb'ande, Njoge and Pandambili were selected for inclusion in the study as shown in Figure 2.

Research design, sampling procedure and data collection methods

The study adopted a mixed method approach that is qualitative and quantitative research designs for effective triangulation of the data. Participatory rural appraisal technique (key informant interview and focus group discussions) and household surveys were therefore adopted during data collection process. The sample frame used during data collection process was purposively selected based on the knowledge and experiences related to the topic of the study. The sample size for the study depended on the method used. A total of six focus group discussions were conducted in each of the six selected study villages. Each focus group comprised of 8 long experienced maize smallholder farmers that is 4 males and 4 females. The size of the group was adopted from Kitzinger (1994) that a group of 8-12 people is easy to handle and manage. Conversely, 12 key informants were reached with key informant checklists including agriculture officials at the ministry level, 2 district agriculture officers from Kongwa and Kondoa district and 6 elderly persons from the sampled villages. Household survey was conducted using household questionnaire whereby a total of 376 households were sampled. The sample size was calculated from Yamane (1976) sample formula depending on the total household in each village therefore household surveyed in Bumbuta were 17, Salanka 88, Bukulu 50, Njoge 86, M'bande 83 and Pandambili 52 respectively. Secondary data included documentation of available rainfall and temperature data for the period between the years 1982 -2017 from Tanzania Meteorological Agency (TMA).

Data analysis

Qualitative data from key informant interviews and focus group discussion were analyzed thematically using Nvivo software. Quantitative data from household perception on the pattern and trend of rainfall and temperature changes for the second objective were cross tabulated using Statistical Package for Social Sciences (SPSS) version 20. The results obtained were confirmed by trend lines and Mann-Kendall trend –two tailed test. Quantitative data for the second objective from household responses on the extent climate change and variability interact with the post-harvest system was analyzed using cumulative percentage estimates in the Statistical Package for Social Sciences (SPSS) version 20. The results obtained were confirmed by canonical correlation test, whereby the Cronch bach alpha test was used to check for the internal consistency of the variables to be above the threshold of 0.7 as recommended by Pallant (2007). Lastly the status of post-harvest losses from household responses was obtained through mean averages of the loss estimates provided by the households across the post-harvest system. Then this study, adopted the 40% estimate provided by Abass et al. (2013) as a threshold value to determine the current status of maize post-harvest losses in the study area formulating two groups that is below 40% and above the 40% threshold values. The final results were then presented in tables and graphs.

RESULTS AND DISCUSSION

Pattern and trend of rainfall and temperature changes in the study area

The study area received unimodal rainfall patterns, which

Figure 2. Map showing location of study area.
Source: GIS LAB –UDSM (2019).

commences by end of November and ends towards early May during the years when the rains are normal but often the rain begins in December and end in early April as shown in Figures 3 and 4. The dry season on the other hand prevails from June to October each year. This unimodal rainfall pattern from December to March within the semi-arid was also reported by Morris et al. (2001) and Schechambo et al. (1999). However, it was revealed that there are traces of wetness during dry season months suggesting the occurrence of rainfall pattern variability that is prolonged wetness into dry season and dryness into wet season due to climate change. Out of 432 months from the year 1982 -2017, Kongwa district experienced 86 months of wetness during dry season and 14 months of dryness during wet season while Kondoa district experienced 243 months of wetness during dry season.

The annual rainfall trend of the study area over the past 30 years was first deduced from household responses. Table 1 presents the percentage of household responses on their perception towards annual rainfall trend in the study area over the past 30 years. Findings show that majority of households in both Kongwa and Kondoa district perceive that there was an increase in annual rainfall amount for the past 30 years while relative few response indicated that annual rainfall amount has been decreasing.

The household response for Kondoa district does not concur with findings in Figure 5 which shows that trend for annual average rainfall in Kondoa district decreases by 0.029mm for every addition of one year. Moreover, the household response for Kongwa district concur with the result in Figure 6 which show that trend for annual average rainfall in Kongwa district increases by 0.0302

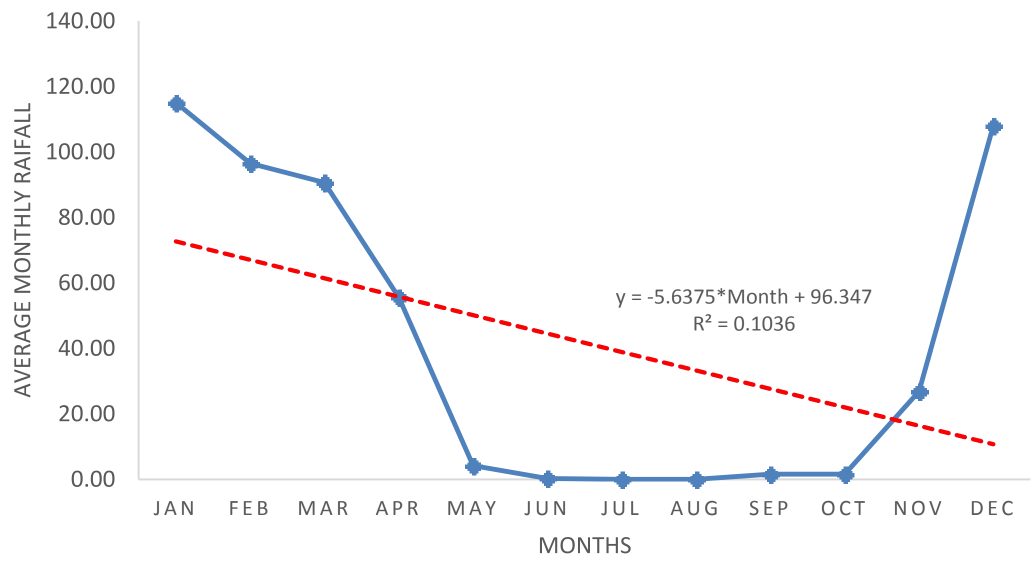

Figure 3. Monthly Average Rainfall from year 1982 -2017 in Kondoa district.

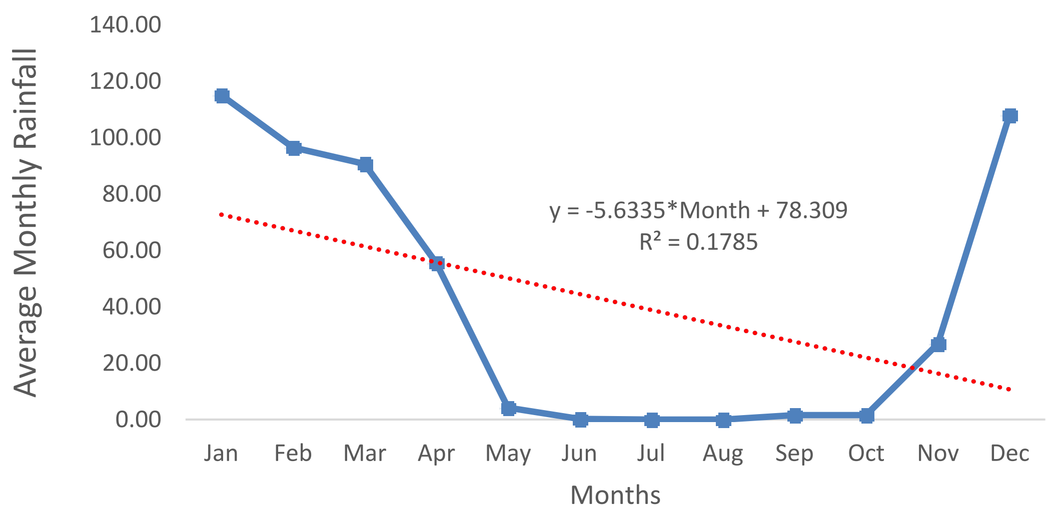

Figure 4. Monthly Average Rainfall from year 1982 -2017 in Kongwa district.

Table 1. Household response on rainfall changes in (%).

District	Villages	Increase	Decrease	No change	Do not know	Total
Kondoa	Salanka	54.9	42.9	1.1	0	100
	Bumbuta	70.6	29.4	0	0	100
	Bukulu	66.0	34.0	0	0	100
Mean % Values		**64**	**35.4**	**0.4**	**0**	**100**
Kongwa	M'bande	80.2	17.3	1.2	1.2	100
	Pandambili	84.6	15.4	0	0	100
	Njoge	80.2	19.8	0	0	100
Mean % Values		**81.6**	**17.5**	**0.4**	**0.4**	**100**

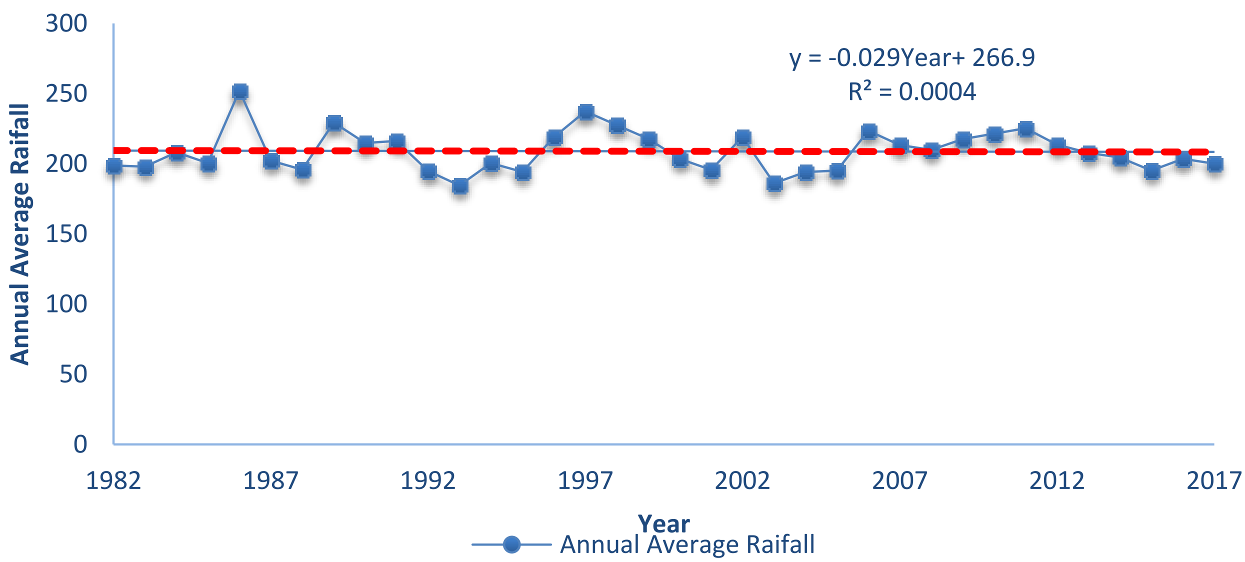

Figure 5. Annual Average Rainfall for Kondoa District from year 1982 -2017.

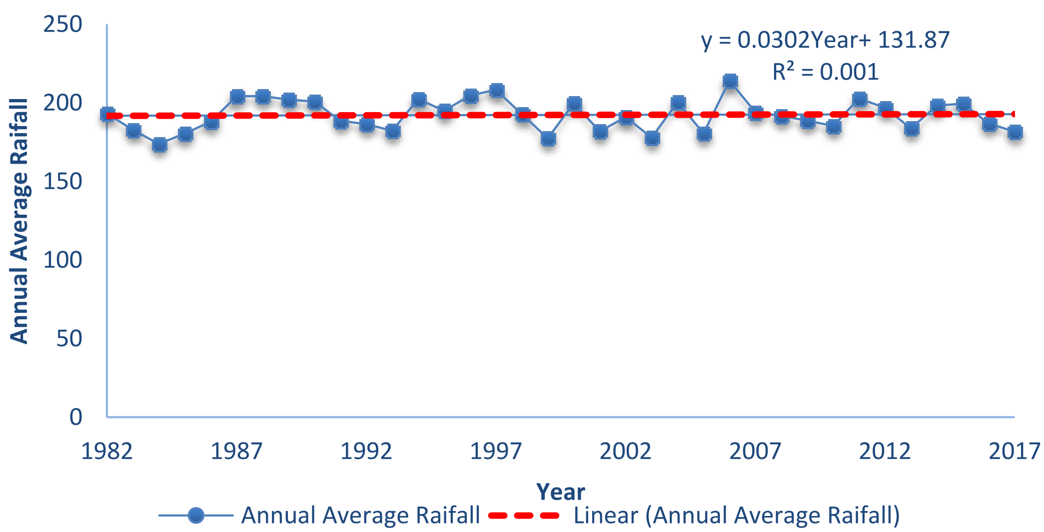

Figure 6. Annual Average Rainfall for Kongwa District from year 1982 -2017.

mm for every addition of one year. This finding suggests that Kondoa district receive less annual average rainfall compared to Kongwa district. However, the results from Mann-Kendell two tailed test as revealed in Table 2 proves that the increasing and decreasing annual rainfall trend in Kongwa and Kondoa district are not significant at p=0.989 and R^2 = 0.0004 for Kondoa district and p=0.924 and R^2 = 0.001 for Kongwa district. This study argues that the household response on the perception of increasing annual average rainfall in both district was based on short term rainfall pattern variability rather than the long term change on annual rainfall. Hence, the study considered the long term annual rainfall changes.

Conversely, findings in Table 3 show that majority of household respondents across the studied villages indicated that annual temperature has been increasing over time compared to those who responded decreasing and no change. This concurs with the results in Figure 7 which indicate that for every additional year from the year 1982 to 2017, temperature has been increasing by

Table 2. Mann-Kendall trend test / Two-tailed test (Kondoa Annual Average Rainfall).

District	Kondoa	Kongwa
Kendall's tau	0.003	-0.013
S	2.000	-8.000
Var(S)	5390.000	5390.000
p-value (Two-tailed)	0.989	0.924
Alpha	0.05	0.05

Table 3. Household responses on temperature changes in (%).

District	Villages	Increase	Decrease	No change	Do not know	Total
Kondoa	Salanka	92.3	3.3	3.3	1.1	100
	Bumbuta	88.2	0	11.8	0	100
	Bukulu	89.4	10.6	0	0	100
Mean % Value		89.9	4.6	5	0.4	100
Kongwa	M'bande	75.3	17.3	6.2	1.2	100
	Pandambili	92.3	5.8	1.9	0	100
	Njoge	84.9	11.6	3.5	0	100
Mean % Value		84.1	11.6	3.8	0.4	100

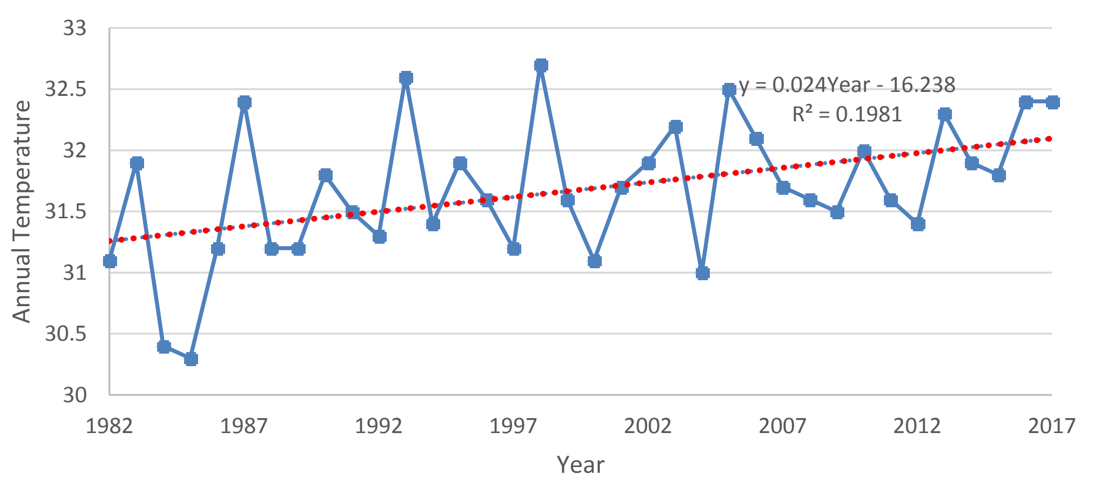

Figure 7. Maximum Annual Temperature for Kongwa and Kondoa district from year 1982 -2017.

0.024°C. This is confirmed by the results from the Mann-Kendall trend test in Table 4 whereby the trend is significant at $p \leq 0.008$ and R^2 0.1981. Moreover, the maximum annual average temperature for the study area was 32.7°C while the minimum of the maximum annual temperature was 30.3 °C with a mean of 31.67 and standard deviation of 0.567. Maximum temperature is normally recorded during the day time, thus its increase reduces soil moisture through evapotranspiration, which in turn negatively affects crop growth (Matata et al., 2019). Similar observation has also been reported by Kabote et al. (2012) in Singida District, Tanzania.

Climate change and variability interaction with maize post-harvest system

The maize post-harvest system in the study area comprise of five stages namely; harvesting, transporting, drying, threshing or shelling and storage. Table 5

Table 4. Mann-Kendall trend test / Two-tailed test (Maximum Annual Average Temperature).

Parameter	Value
Kendall's tau	0.314
S	194.000
Var(S)	5355.333
p-value (Two-tailed)	0.008
Alpha	0.05

Table 5. Household responses on climate change impacts interaction with maize post-harvest system in %.

District	Harvesting	Transporting (%)	Drying (%)	Threshing or shelling (%)	Storage (%)
Kongwa	29	9	10	8	44
Kondoa	23	11	9	9	48

presents percentage of cumulative estimates of household responses towards climate change influence on maize post-harvest losses. Findings show that households in the study area perceive that climate change and variability interact with all stages of the maize post-harvest system but more during storage and harvesting as compared to the other stages. The inclusion of storage stage in this finding concur with Abass et al. (2013) that an estimate of 40% losses of cereal crops is experienced during storage, indicating that huge post-harvest losses occur at this stage. The difference in perception of the post-harvest losses between Kongwa and Kondoa district is based on the nature and origin of the pre harvest system, since the amount of food lost across the post-harvest system is dependable and controlled by the amount lost and produced in the pre harvest system.

The results from canonical correlations test in Table 6 concur with households responses that climate change and variability impact interact more with the maize post-harvest system during harvesting and storage stage. The results shows that the general fit of the model especially the Wilk's lambda is statistically significant at 0.05 levels, hence, the null hypothesis was rejected that the two canonical covariates (temperature and rainfall) are the same and that the assumption of multivariate normality has been satisfied. The first canonical dimension shows that it was statistically significant at 0.05 and had the variability of up to 76%, while the second canonical dimension was not statistically significant and had less variability of approximately 24%. Hence, the first canonical dimension was used to explain the results, and it was strongly positive correlated with both temperature and rainfall perception scores with a correlation of R^2 = 0.971 and 0.843 respectively. On the other hand, for the other pair of variable, the canonical variable is weakly positively correlated with harvesting and strongly negatively correlated with drying with a correlation of R^2 = 0.014 and -0.733 respectively. In addition, storage has a weakly positive correlation of R^2 = 0.121 with the canonical variable while both transportation and threshing and selling had a negative association with the canonical variable with a correlation of R^2 = -0.218 and -0.376 respectively. Therefore, this study confirms household perception that climate change and variability influences food losses in the maize post-harvest system losses but is significant at p= 0.05 during harvesting and storage.

The interaction between climate change and variability impacts with maize post-harvest system is therefore deduced from rainfall and temperature changes, specifically from the monthly rainfall changes and annual temperature increases since the annual rainfall trend showed no significant increase and decrease trend. The monthly rainfall changes influences maize post-harvest losses through the presence of wetness during the months of dry season which are often the months when harvesting of maize occur (that is from June – August). Conversely increase in temperature influences post-harvest losses through increased eruption of crop pests and diseases as indicated by Bebber et al. (2013). It was revealed that maize in the study area is currently affected with increased eruption of fall army worms. the fall army worms prefers feeding on young tender maize leaves which often sprout in rainy season. Fall Armyworm is an insect that is native to tropical and subtropical regions of the Americas but have develop mechanisms to adapt to different climates (Sarmento et al., 2002). According to Capinera (2007), temperature has a significant influence on the fall army worm life cycle such that when temperature is higher it completes its lifecycle in about 30 days.

During harvesting, rain water penetrates into the maize grain through inlets made by insect and bird's damage on maize cobs. Increased infestation of crop pests and diseases weaken and damages the maize cob hence increasing its susceptibility to fungal infections particularly

Table 6. Multivariate Test of Significance.

Test Name	Value	Approx. F	Hypoth. DF	Error DF	Sig. of F
Pillais	0.078	1.737	10.00	430.00	0 .031
Hotellings	0.081	1.741	10.00	430.00	0 .012
Wilks	0.923	1.739	10.00	430.00	0 .033
Roys	0.058				
Note.. F statistic for WILKS' Lambda is exact.					
Eigenvalues and Canonical Correlations					
Root No	**Eigenvalue**	**Pct.**	**Cum. Pct.**	**Canon Cor.**	**Sq. Cor**
1	0.01972	97.95345	97.95345	0.13908	0.01934
2	0.00041	2.046555	100.00000	0.02030	0.00041
Dimension Reduction Analysis					
Roots	**Wilks L.**	**F Hypoth.**	**DF**	**Error DF**	**Sig. of F**
1 TO 2	0.98025	3.50204	6.00	384.00	0.004
2 TO 2	0.99959	1.29248	2.00	193.00	0.024
Correlations between DEPENDENT and canonical variables					
Canonical variable					
Variable	1				
Total score on temperature perception change	0.971				
Total score on rainfall perception change	0.843				
Correlations between COVARIATES and canonical variables					
CAN. VAR.					
Covariate	1				
Harvesting	0.0146				
Transporting	-0.2187				
Drying	-0.7336				
Threshing and selling	-0.3766				
Storage	0.1210				

EFFECT. WITHIN CELLS Regression
Multivariate Tests of Significance (S = 2, M = 0, N = 95)
Source: Fieldwork (2018).

A. flavus and hence continued contamination with aflatoxins. Since the fungal resides in the soil and spread through air from the soil (Sumner and Lee, 2017), then contamination with the harvested maize is inevitable since the harvested maize cobs in the study area are lumped directly on the ground. Upon contact with the maize cobs and the presence of moisture, the fungal begins to sprout and produce aflatoxins which can be detected through color changes in maize grain and lead to complete decay of maize cob as shown below. Moreover, during storage, increase in atmospheric temperature also affects storage room temperature creating humidity which produces moisture that favors fungal growth to the stored maize.

This study have only considered the relation of temperature and rainfall with aflatoxin contamination on the maize crop however study by Medina et al. (in press) have managed to consider the three way relationship between rainfall, temperature and carbon dioxide with aflatoxin contamination (Plate 1).

Apart from climate change and variability influence on maize post-harvest losses, it was also revealed that other factors that contribute to post harvest losses includes (i) inadequate and poor harvesting tools and skills resulting into scattering of maize grains or cobs in the farm, (ii) poor transport facilities which contribute to reduced maize quantity through leakage holes in the transporting facilities used, (iii) poor drying facilities often on the bare ground subjecting the maize to fungal infection due to presence of moisture in the soil, livestock feed, rodents and termites, (iv) poor packaging materials, and (v) poor storage facilities, such as lack of air circulation in the storage room which lead to fungal infections but also rodents and pests.

Plate 1. Discolored maize grain and decayed maize cob due to aflatoxin contamination.

Table 7. Household responses on the status of maize post -harvesting and storage losses

Post-harvest level	Threshold level	Kongwa District			Kondoa District		
		Salanka	Bumbuta	Bukulu	Mbande	Pandambili	Njoge
Harvest	Below 40%	96	94	97	94	88	82
	Above 40%	4	6	3	6	12	18
	Total	**100**	**100**	**100**	**100**	**100**	**100**
Storage	Below 40%	85	88	95	91	81	72
	Above 40%	15	12	5	9	19	28
	Total	**100**	**100**	**100**	**100**	**100**	**100**

Source: Fieldwork (2018)

Status of maize post-harvest losses in Kongwa and Kondoa District

In the previous section, the study confirmed that temperature and rainfall significantly influences more losses during harvesting and storage. Therefore, Table 7 presents the cumulative estimates of the status of maize post- harvest losses occurring during harvesting and storage in categories that is above and below 40% threshold level as provided by Abass et al. (2013). The aim was to establish the status of maize post- harvest losses in the studied area against the provided estimates.

Findings indicate that in both Kongwa and Kondoa districts the majority of households experiencing maize post-harvest losses during harvesting were below the 40% threshold. This implies that maize post-harvest losses occurring during harvesting in the study area are low because household’s responses are below the threshold of 40%. Conversely, the status of household maize post-harvest losses occurring during storage also indicate that majority of the households in both Kongwa and Kondoa district are experiencing maize post-harvest losses below the threshold of 40% as compared to those experiencing losses above the 40% threshold. This also implies that maize losses occurring during storage are low since majority of households responses were below the 40% threshold.

Conclusion

The influence of climate change and variability on post-harvest losses is through annual temperature increase and monthly rainfall pattern changes. Although the post-harvest system comprises of five stages, the influence of temperature and rainfall variation on post-harvest losses is more reflected during harvesting and storage. This occurs through provision of favorable conditions such as moisture, humidity and optimum temperature for fungal growth on the maize cob which produced aflatoxin – a toxic chemical which is lethal to human health upon consumption. Increase in temperature also favors pest outbreak which causes damage on the maize cob hence subjecting the crop to aflatoxin contamination. The current statuses of maize post-harvest losses are below the threshold values but are significant in contributing to household food insecurity. This study therefore recommends increased awareness program to local farmers in the villages on the impacts of climate change on the post-harvest food losses and their contribution to household food insecurity through training, seminars, workshop and campaigns. This will encourage effective adoption of climate change and variability coping mechanisms with continued mitigation practices through increased afforestation and reduced deforestation.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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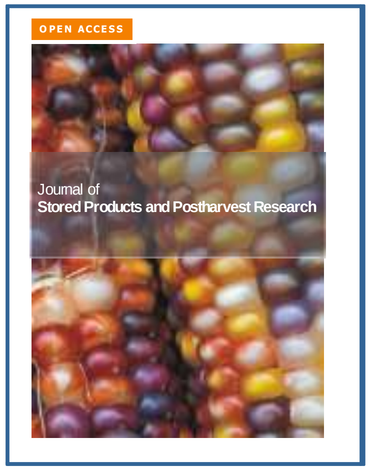

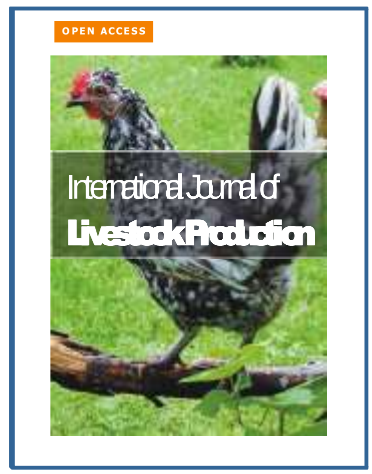

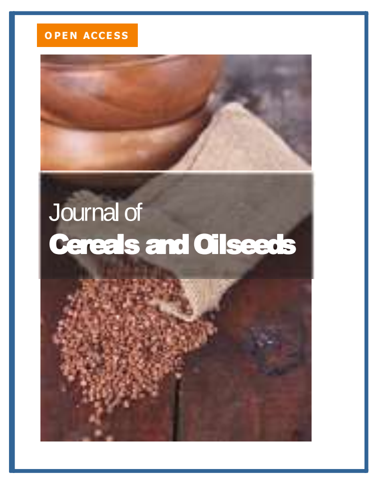

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