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Journal of Agricultural Biotechnology and Sustainable Development

Full length Research Paper

Do fertilizers and cropland influence the agricultural production value in the same way? Evidence using the autoregressive distributed lags approach of cointegration

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Cropland and fertilizers are two prominent and non-spared factors of agricultural sustainable production. This study mainly aimed to examine the response of crop production value to cropland used and chemical fertilizers supplied by using the Autoregressive Distributed Lags approach of cointegration over the period 1980 to 2016. The bound test and the error correction term showed that the amount of nitrogen (*N*), phosphorus (*P*) and potassium (*K*) consumed, the optimal ratio *N-P-K* applied, the amount of hectares cultivated for temporary and permanent crops are strongly linked to the growth of crop production value. The results may be analyzed following three ways: in the long-term, both cropland used and fertilizers ratio supplied appear greatly to induce a positive impact; in the short-term, the previous farming activity on a cropland might provide a positive influence; even though fertilizers' *ratio* supplied may not induce a substantial effect in the short-term, however, fertilizers nutrient supplied solely may impact the production value. In addition, the number of machines and the labor force are shown to foster the growth of crop production value in the long-term and short-term respectively. For the sake of agricultural sustainability, the findings support a farming system including a complementarity between multi-planting with high nitrogen nutrient requirements, trees plantation (agroforestry) and mechanization.

Key words: Fertilizer, cropland, crop production, sustainable agriculture, auto regressive distributed lags model.

INTRODUCTION

Nutrients management and land management are two key challenges to deal with for global food production and agricultural sustainability. The latter consists of environment friendly practices of farming (crop rotation,

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multi-cropping, agroforestry, land management, etc.) and technologies use (Nutrients and pests management, etc.) that allow the production of crops without damages to human or natural systems.

In recent years, crop production per hectare increasingly depends on agricultural science and technology advances, farm infrastructures, fertilizers use, pesticides use, planting structures for crops, water management and policy for agriculture production. Different input factors have different influences on agricultural production. For instance, while the Integrated Pest Management (IPM) seeks to use pesticides when other options are ineffective (Hassanali et al., 2008; Bale et al., 2008), the Integrated Nutrients Management (INM) seeks to balance both organic and inorganic fertilizers (Goulding et al., 2008; Ahmad et al., 2011). Indeed, the ideal should be the development of organic farming. (Anup et al., 2017; Verena et al., 2017; Zeynab et al., 2017). However, it must mainly benefit from the system of financial supporting order to encourage certain farmers to change a manner of production to a more environmentally friendly one, or to avoid the decision of others to resign from production using ecological methods (Iwona and Marta, 2017).

Inorganic fertilizers are chemical compounds applied either through the soil or through plants leaves to promote the growth. Fertilizer plays a vital role in achieving high level of production by providing essential plant nutrients (Olowoake and Ojo, 2014; Ramasamy et al., 2013). Nitrogen nutrient is recognized to offer the green impact and foster the photosynthesis, phosphorus is destined to play a major role in root growth and energy transfer activities within the plant, whereas potassium is supposed to help plants in flowering and fructification. Balanced fertilization is one of the most important farming tools, given that it enables a rational use of fertilizers with other inputs for a best possible supply of all essential nutrients.

Actually, famers used to resort to more chemical fertilizers for the purpose of increasing crops production in response to diverse constraints they face while bringing more area under cultivation and while restoring deficiency of nutrients in soil (Planning Commission of India, 2011). Owing to these serious concerns, sustaining agricultural production growth and yield requires nowadays the application of fertilizer best management practice (Roberts, 2007) which is summed up under the term “4Rs” namely: right product, right rate, right time and right place. Otherwise, the consequence of excessive use of chemicals beyond the limit of absorption of the plants might cause secondary effects to the soil and the plants (Doll and Baranski, 2011). Many other factors should be considered in the expectation of drawing a great impact from fertilizers use.

Lonester et al. (2017) found that when they are subsidized, fertilizers may not only increase farmers’ market participation as sellers, but also raise the total quantity of crop sold, and favor crop commercialization. Lenis et al. (2017) suggest that except dropping transportation costs, other constraints such as soil quality, timely access, availability of complementary inputs (for example, improved seeds, irrigation and credit), as well as good management practices on farmland are also necessary for improving the profitability of fertilizers use. For concerns regarding farmland or even ecosystem services, Powlson et al. (2011) advocate the management of deforested land, conversed grasslands to arable cropping and drainage of wetlands in relation to sustainable agriculture practices.

In this context, Jill Caviglia-Harris (2003) found the slash-and-burn practice to be inconsistent with sustainable agriculture compared to those such as agroforestry, apiculture and aquaculture, rather it may cause deforestation with all its consequences. In other words, the conversion of forests to cropland would entail major environmental costs (Jordan et al., 2014).

Accordingly, Jayne et al. (2014) propose that agricultural and rural development strategies need to more anticipate the implications of rapidly changing land. Furthermore, a number of researches are conducted in investigating on the long-term effects of single fertilizers upon the soil fertility and productivity (Bi et al., 2014; Suman et al., 2016; Venkatesan et al., 2004). Following Kumar and Yaday (2008), the yield response of grains further to a direct nitrogen fertilizer supply would decline over the long period. In contrast, the application of phosphorous and potassium over time would allow the grains yield to increase. Their findings also revealed that balanced doses of nitrogen, phosphorous, and potassium are required to maintain durably soil fertility and boost the grains yield.

The present research does raise the main question that how are chemical technologies use and cropland management linked to the agricultural production value? And, are the influence of fertilizers supplied and the influence of cropland cultivated complementary over the years? The main objective of this study is to analyze the evolution of the relationship between chemicals, cropland and crop production value over the years. The methodological approach is based on time series data over the period 1980 to 2016 pertaining to the country of Benin[1], and then, using the Autoregressive Distributed Lags (ARDL) model of cointegration (Pesaran and Shin, 1999; Pesaran et al., 2001). The attention is mostly directed on the influence of single fertilizer use, combined fertilizers supply as well as cultivated cropland in the short and long terms, and then, the corresponding suggestions are put forward.

[1]A country located in the Western Africa,Benin is a tropical nation, highly dependent on agriculture, with substantial employment and income arising from subsistence farming. Its climate is hot and humid. It has two rainy and two dry seasons per year.

Modeling and data description

Theoretical modeling

The mathematical equation estimated in this study is based on Cobb-Douglas (C-D) production function. It may be written as:

$$Y = A_0 \exp(\delta t) \prod_{i=1}^{p} X^{\alpha_i} \quad (1)$$

where Y isthe output or income value, A_0 is the level of the output or income at the base period, exp represents the exponential function, **δ** is the parameter of technological progress, t indicates the time variable expressing the influence of technological progress, p is the number of factors of production, X is a matrix of factors of production and α_i is the parameter of ith factor of production. It may be demonstrated that the α_i are the output or income elasticity coefficients. Thus, seeking the partial derivative on *X* in Equation (1), we can get:

$$\alpha_i = \frac{\partial Y}{\partial X_i} \times \frac{X_i}{Y} \quad (2)$$

X_i is the ith factor of production. The values of α_i are obtained by applying the logarithm on both sides of equation (1). Thus, the basic specification is given as follows:

$$ln(Y) = ln(A_0) + \delta t + \sum_{i=1}^{p} \alpha_i \, ln(X_i) \quad (3)$$

where ln represents the logarithm function.

Availability of data and materials

The dataset supporting the conclusions of this article are included within the article its additional files. The study is based on annual time series data of 37 observations (1980 to 2016) obtained from different sources, including the Food and Agriculture Organization of the United Nations (FAO), and the United Nations Conference on Trade and Development (UNCTAD). Table 1 provides variable definitions and data sources. Figure 1 provides information that a linear equation model may describe correctly the relationship between the variables of interest. It shows that the number of machines used, the labor force, and the number of hectares cultivated for temporary and permanent crops are positively related to the growth of crop production value. Meanwhile, the impact of chemicals would be positive over time when they are supplied as direct fertilizers, but the obviousness of their linear relationship with the growth of crop production value does not appear so strong.

RESULTS AND DISCUSSION

This section is devoted to unit-root test, appropriate ARDL model selection, bound test, long-run equation estimation, and short-run equation estimation. Following the study of Odhiambo (2009) and Narayan and Smyth (2006), the long-run relationship between variables indicates that there is Granger-causality in at least one direction which is determined by the F-statistic and the coefficient of the lagged error correction term.

Unit-root test on variables

The application of the ARDL approach requires that no variable is integrated of an order more than one. Table 2 shows that this requirement is met given that therein, no variable is found to be I (2).

Selection of appropriate ARDL model

The optimum lag order (*k*) is selected by referring to Akaike Information Criterion (AIC). The ARDL model of equation (4) with lag 4 (AIC=-8.579143) is found to perform relatively better.

$$Dy_t = a_0 + \alpha y_{t-1} + \sum_{n=1}^{T} \beta_n X_{n,t-1} + \sum_{i=1}^{k} \gamma_i \, Dy_{t-i} + \sum_{n=1}^{T} \sum_{i=1}^{k} \delta_{ni} \, DX_{n,t-i} + \varepsilon_t \quad (4)$$

where, D symbolizes the first difference operator, y is the dependent variable, X_n is a matrix of explanatory variables, a_0, α, β_n, $\gamma_i \delta_{ni}$ are coefficients (*i* expressing the number of lag). The tests of suitability showed that the specified ARDL model is free from serial correlation and heteroskedasticity. On the other hand, the model appears to be stable in the sense of recursive residual test for structural stability. Moreover, the null hypothesis that the residuals are normally distributed cannot be rejected (Figure 2).

Bound test of cointegration

The bound test (Wald test) is given in Table 3. It is run through the Prob.Chi-square. Since this probability is less than 5%, the null hypothesis that all long-run coefficients are jointly equal to zero cannot be accepted. In addition, t-statistic tests are run on both the dependent and independent variables in order to avoid degenerate cases**.** Therefore, we do conclude that the variables of interest are bound together, in other words, they are cointegrated.

Estimation of long-run coefficients

Based on equation (3), the growth of crop production value is estimated by a long-run model (Table 4). The regression model performs well, predicting 99% of the specified equation correctly. The causality between the value of crop production and its determinant factors is established through the F-statistic. The residuals coming from the estimation are normally distributed and the diagnostic does not reveal any problem of serial correlation and heteroscedasticity.

In addition, the null hypothesis that the coefficients of dummies are equal to zero cannot be accepted, meaning that the other factors above-mentioned have influenced significantly the growth of crop production value over the

Table 1. Variable definitions and data sources

Variable	Definition	Sources
VCROP	Value of agricultural crop production (constant 2004-2006, 1000 International US dollars)	FAO, 2017
N	Number of tons consumed as nitrogen fertilizer	FAO, 2017
P	Number of tons consumed as phosphorus fertilizer	FAO, 2017
K	Number of tons consumed as potassium fertilizer	FAO, 2017
*RATIO**[1]	Ratio between nitrogen, phosphorus and potassium	Determined by the author
ALAND[2]	Number of hectares cultivated for arable land & permanent crops	FAO, 2017
MACHIN	The number of machines (tractors, harvesters, threshers) used	FAO, 2017
LABOR	Number of persons having participated in the agricultural crop production	UNCTAD, 2017
*Dum**[2]	Dummy variable for other potential determinant factor; 1, 0	Determined by the author

[1]Note: Ratio*, denotes the combination *N-P-K*. It is expressed like a dummy variable that takes the value "1" except for the years 2007, 2008, 2010 and "0" otherwise. It is obtained through the following two steps: (1) dividing each annual amount of fertilizer by its corresponding annual amount of *K* and getting two groups of combinations, the first group being recognized as optimal ratios (Srivastava and Ethel, 2009), and the second,as non-optimal ratios (refer to year 2007, 2008 and 2010); (2) affecting the value "1" when the ratio is supposed to be optimal and the value "0" otherwise. Thus, the variable *Ratio* measures the optimum requirement of inorganic fertilizers recommended for sustaining agricultural crop production.
*[2] Note : *Dum*, is a dummy variable introduced in order to capture the impact of other factor such as water management, new varieties of seed adoption, pesticides management,public technical and financial assistance, and natural phenomena (for example, flooding, precipitations).

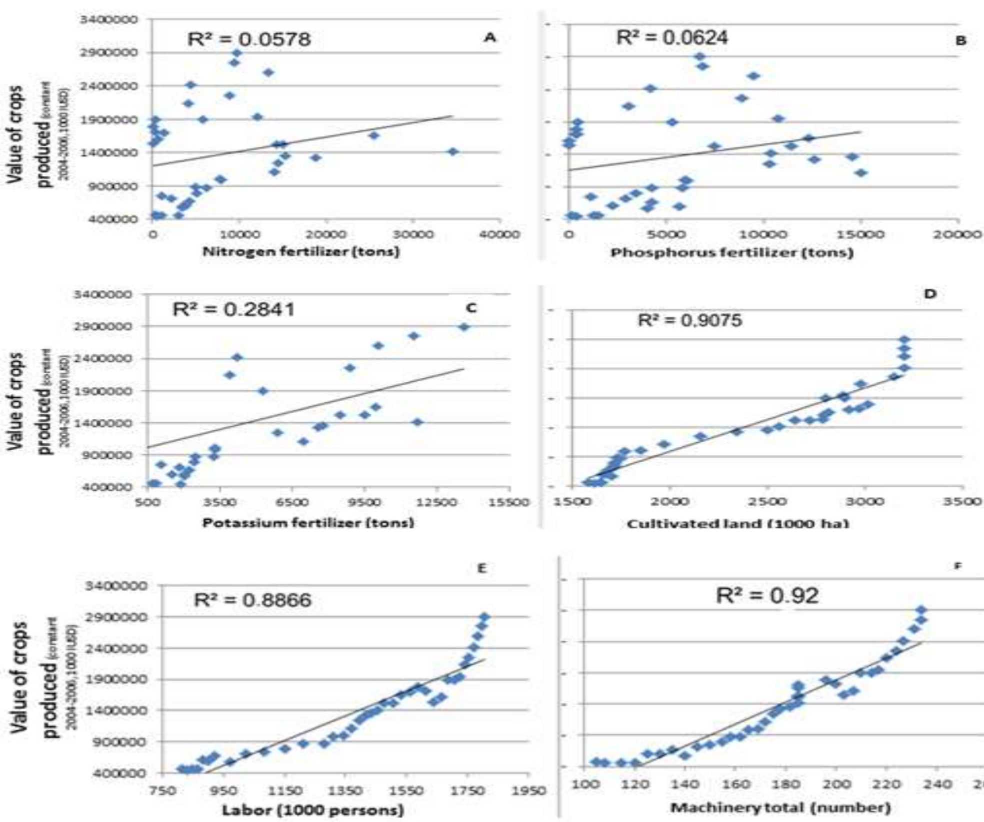

Figure 1. (a) Relationship between nitrogen fertilizer used and value of crops produced (1980-2016). (b) Relationship between phosphorous fertilizer used and value of crops produced (1980-2016); (c) Relationship between potassium fertilizer used and value of crops produced (1980-2016); (d) Relationship between cultivated land area and value of crops produced (1980-2016); (e) Relationship between labor force used and value of crops produced (1980-2016); (f) Relationship between number of machines used and value of crops produced (1980-2016).

[2] According to the FAO, "Arable land" refers to land producing crops requiring annual replanting or fallow land or pasture used for such crops within any five-year period" (multiple-cropped areas are counted only once).A briefer definition appearing in the Eurostat glossary similarly refers to actual, rather than potential use: land worked (ploughed or tilled) regularly, generally under a system of crop rotation.
"Permanent cropland", meanwhile, refers to land producing crops which do not require annual replanting. It includes forested plantations used to harvest coffee, rubber, or fruitbut not tree farms or proper forests used for wood or timber.

Table 2. ADF unit-root test[3] on variables.

Variable	Unit-root test in[4]	ADF test statistic	Test critical values	Integration order
LVCROP	First difference, including intercept	-8.303335	-3.632900***	I (1)
LN	First difference, including intercept	-3.266967	-2.954021**	I (0)
LP	First difference, without intercept nor trend	-5.432033	-2.632688***	I (1)
LK	First difference, including intercept	-3.797912	-3.661661***	I (0)
LALAND	First difference, without intercept nor trend	-2.488680	-1.950687**	I (1)
LMACHIN	First difference, including intercept	-5.590737	-3.626784***	I (0)
LLABOR	First difference, including intercept	-13.69832	-3.670170***	I (0)

***Indicates significance at the 1% level; ** Indicates significance at the 5% level.

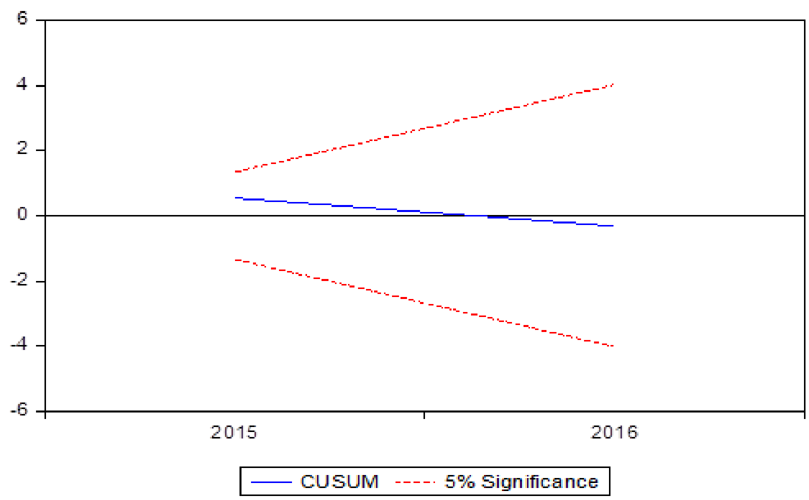

Figure 2. Stability diagnostic test on the ARDL model.

Table 3. Bound test for cointegration.

Wald test for joint significance:			
Null hypothesis: The coefficients of all lagged variables below are jointly equal to zero			
Test statistic	Value	df	Probability
F-statistic	160.0389	(7.2)	0.0062
Chi-square	1120.272	7	0.0000
T-statistic tests on lagged variable			
variable		**Value**	**Std. Err.**
LVCROP(-1)		-2.523529***	0.256349
LN(-1)		-0.259071***	0.024411
LP(-1)		0.230906***	0.019822
LK(-1)		0.103154**	0.018871
LALAND(-1)		1.594530**	0.234670
LMACHIN(-1)		1.336539*	0.353814
LLABOR(-1)		2.384072***	0.148744

***Indicates significance at the 1% level; ** Indicates significance at the 5% level; * Indicates significance at the 10% level.

[3] From Eviews software
[4] Maxlag = 9

Table 4. Estimated long-run coefficients.

Sample : 1980-2016 (*N = 37*)		
Variable	**Coefficient**	**S.E.**
Constant	-44.61761***	8.803430
YEAR	0.025609***	0.005060
LN	0.082994***	0.025639
LP	-0.035049**	0.016360
LK	-0.025460*	0.015035
RATIO	0.292208***	0.096638
LALAND	0.378562***	0.0111098
LMACHIN	0.554333*	0.288178
LLABOR	0.163634	0.199811
Dum87	-0.171571***	0.043469
Dum83	-0.214864***	0.046609
Dum08	0.261608***	0.078125
Dum04	0.186459***	0.059152
Adjusted R^2	0.994	-
F-statistic	592.177***	-
Durbin-Watson stat (DW)	2.014	-

***Indicates significance at the 1% level; **Indicates significance at the 5% level; *Indicates significance at the 10% level.

period of study. The results indicated that the growth of crop production value (*VCROP*) was influenced by all the explanatory variables except *LABOR*. The technological progress appears greatly to be a major determinant of boosting the productivity of limited input factors, notably land factor (Fan, 1991).

When nitrogen is supplied as a direct fertilizer, its impact on the growth of crop production would be significantly positive in a relatively long period. This outcome seems to be quite substantial in the sense of evergreen production according to the role played by the said factor (Tables 3 and 4). Unlike nitrogen, the impact of phosphorus and potassium nutrients appears unobvious. Even though previous research (Kumar and Yaday, 2008) contradicts this result, it nevertheless, proposes the experimentation of balanced doses of N-P-K for maintaining durably soil fertility and boosting the grains yield. Indeed, the variable *Ratio* in this study appears greatly to be positively related to the growth of crops production. Thus, once plants fertilization is performed at 100% in an optimal way, ceteris paribus, it would foster an increase in the value of crop production by approximately 29%. However, with regard to food security goal, policies and actions are needed to make the chemical technologies available and affordable to small farmers (Pedro et al., 2016; Powlson et al., 2011).

In the other hand, policies and strategies seeking to manage more efficiently the flows of nutrients in ways that minimize environmental damage should be taken in both developed and developing rapidly areas. Beyond all the aforementioned concerns, nutrients should be applied in accordance with soil characteristics that differ from a country to another. For instance, Niu and Hao (2017) found the treatment with 270 kg N/ha/year and 59 kg P/ha**/**year to represent the most economical fertilizer rates for salt-affected soils on the North China plains.

The number of hectares cultivated (*ALAND*) would influence positively the growth of crop production value. This result is similar to that obtained by Luo and Huang (2013). Since the variable includes agricultural sustainable practices, the outcome may be viewed as highlighting the fact that associating permanent crops cultivation with temporary crops on a same farm land might greatly impact the growth of crop production and its sustainability. In other words, such a farming system may appear effective to slow down deforestation or extension of arable land (Caviglia-Harris, 2003; Derek et al., 2014). In the country of Benin, a number of small farmers do draw a significant benefit from permanent cropping (for example, coconut, palm, cashew, mango) and the concerned staple crops are included in the basket of main commodities for export.

The number of machines is destined to capture the importance of agricultural mechanization (labor-saving technology). It's found that as the number of machines (*MACHIN*) increases so does the value of crop production. This outcome, not only appears consistent with Futoshi (2016) by emphasizing that machines and land must be complementary, but it also highlights that optimal fertilization ratios and land management should move together for the sake of food security and agricultural sustainability (United Nations, Sustainable Development Goal 2)[5]. Furthermore, the residuals coming from the long-run estimation are found to have no unit-root at level.

[5] Goal 2: End hunger, achieve food security and improved nutrition and promote sustainable agriculture

Table 5. Estimated short-run coefficients by ARDL approach.

Sample : 1980-2016 (*N = 37*)		
Variable	**Coefficient**	**S.E.**
Constant	0.549283	2.162844
YEAR	-0.000244	0.001072
DLVCROP(-1)	-0.129895	0.112322
DLN(-1)	-0.004808	0.012730
DLN(-2)	0.004805	0.014712
DLN(-3)	0.022353*	0.011130
DLP(-1)	-0.007066	0.010792
DLP(-2)	-0.017329	0.011796
DLP(-3)	-0.021823**	0.008621
DLK(-1)	0.006503	0.006488
DLK(-2)	0.019952***	0.006048
DLK(-3)	0.019459***	0.004613
RATIO	0.019314	0.030211
DLALAND(-1)	0.752711*	0.367390
DLALAND(-2)	-2.220779***	0.524459
DLMACHIN(-1)	-0.469284	0.718629
DLLABOR(-1)	4.482919***	1.309953
DLLABOR(-2)	-4.342043***	1.228740
ECT(-1)	-0.683089**	0.270060
Dum87	-0.165441***	0.033625
Dum84	0.266409***	0.043888
Dum96-00	0.109121***	0.033782
Dum94	0.115597**	0.046167
Adjusted R^2	0.886	-
F-statistic	12.3116**	-
Durbin-Watson stat (DW)	1.75	-

***Indicates significance at the 1% level; ** Indicates significance at the 5% level; *Indicates significance at the 10% level.

Estimation of short-run coefficients

The short-run model (Table 5) performs well, predicting 89% of the specified equation correctly. The model passed through all the econometric diagnostic tests, and the null hypothesis that the coefficients of dummies are equal to zero cannot be accepted. The parameter of the lagged Error Correction Term is significantly negative, confirming the existence of a long-run convergence of the underlying variables. This implies that any disequilibrium in the previous period is adjusted at a speed of 68% to the current period.

Empirically, the response of crop production growth to variables lagged by one-period relating to fertilizers is found unobvious. Meanwhile, the results show that fertilizers applied solely since three years or two years (case of potassium) might impact significantly the growth of crop production value for the current period. This seems to highlight the importance of laying fallow a cropland for at least two years. In other words, the effect produced by *N*, *P or K* nutrients applied today would be more effective in a medium-long term.

Moreover, the two-period lags and one-period lag of the variable *Aland* displayed a solid relationship with the growth of crop production value. In other words, current period's land management (farming practice, fertilizers, water, weed, and pest management, etc.) may foster crops grown in the next period. Therefore, postharvest state of cropland should be well handled in order to draw profit from postharvest positive externalities generated by, among others, crop residues, manures applied, synthetic fertilizers, energy used.

The short-run estimation showed that the variable *labor* does follow the same trend with that designating farming system (*ALAND)* in terms of the generated effect. The findings indicated that the quality and quantity of labor force engaged today appear greatly to be related to the production value expected in the following period. However, apart from Derek and Jayne (2014), Jayne et al. (2014) state that the enormous challenges that mounting land pressure do take source from a rapidly rising labor force associated with demographic conditions, and limited nonfarm job creation.

The result does not reveal an obvious influence of one-period lag of the variable *MACHIN*. However, as discussed earlier, machines should be used in complementarity with land management in pursuance of food security and sustainable agriculture goal.

After all, the findings coming from the short-run and long-run estimations may be summed up as follows (Table 6) with assumption that agricultural sustainable practices (namely multi-cropping and agroforestry) are

Table 6. Summary of potential effect of chemical fertilizers and cropland.

Period	**Long-run**					**Short-run**				
Variable	*N*	*P*	*K*	*Ratio*	*ALAND*	*N*	*P*	*K*	*Ratio*	*ALAND*
Number of lag (Maxlag=3)				-		1, 2, (resp. (3))	1, 2, (resp. (3))	1, (resp. (2, 3))	-	1, (resp. (2))
Influence on crop production growth	+	-	-	+	+	Unclear, (resp.(+))	Unclear, (resp.(-))	unclear, (resp. (+))	Unclear	+, (resp. (-))

conducted on the cropland. The ultimate objective here is to direct attention on the matter to take into account during the ex-ante and the postharvest management of cropland.

Conclusion

This research examined the dynamic response of crop production value to cropland use and chemical fertilizers supply by using the Autoregressive Distributed Lags approach of cointegration over the period 1980-2016. The bound test and the Error Correction term determined that the amount of nitrogen (*N*), phosphorus (*P*) and potassium (*K*) consumed, the optimal ratio *N*-*P*-*K* applied, the amount of hectares cultivated for temporary and permanent cropsare strongly linked to the growth of crop production value. In compliance with the main objective, the findings may be summarized in three ways:

(a) In the long-term, both *cropland* used and fertilizers *ratio* supplied appear greatly to induce a positive impact.
(b) In the short-term, previous farming activity on a c*ropland* might induce a positive influence in the current period.
(c) Even though fertilizers' *ratio* supplied may not induce a substantial effect in the short-term, however, fertilizers nutrient supplied solely may impact the production value.

In addition, the number of machines used and the labor force appear to be significant in the long-term and the short-run respectively (Table 6). For the sake of food security and agricultural sustainability, the findings support a farming system that completes multi-planting with high nitrogen nutrient requirements, trees plantation (agroforestry) and mechanization. This suggestion appears attractive following Berihun et al. (2014), George (2014) and Megan and Christopher (2017) for the fact that the agricultural technology adopted is likely to be linked with farm income.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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Challenges and opportunities of honey production in north- east dry land areas of Amhara National Regional State, Ethiopia

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The study aims to evaluate major challenges, opportunities and future prospects of bee keeping and honey production in three districts of Waghimra Zone (Abergell, Sekota and Gazgibala**). To collect data, 332 respondents were selected using systematic random sampling from the three districts. Data were collected using semi-structured questionnaire, observation, keyinformant interveiw and focus group discussion. Data were analyzed using descriptative statistics and analysis of variance (ANOVA) using statistical package for social science (SPSS) version-20. The results of this study indicated that beekeeping is one of the most important income generating activities besides other agricultural activities. The major challenges identified were prevalence of pests and predators, recurrent drought, indiscriminate application of pesticides and herbicides, lack of bee forage associated with deforestation, lack of credit service for the beekeeping sector, absconding and migration of bee colonies, high cost and limited availability of modern beekeeping equipment's and accessories, shortage of water, and lack of skill in beekeeping management. It has been revealed that the opportunities for beekeeping in the study areas were the existence of abundance of honeybee colonies, availability of potential flowering plants, sources of water for bees, increasing market demand for beehive products, existence of soil and water conservation practice and area enclosure in the area, beekeepers' experience and indigenous knowledge and socio-economic value of honey. Thus, based on these findings, improving the awareness of the beekeepers through training and strong extension service, supplying cheap bee keeping inputs, capacitating to beekeepers to control the pests and predators are important to address the identified challenges and to improve the overall honey production in Waghimara Zone.**

Key words: Bee colony, beehives, beekeeping, challenges, honey production, opportunities.

INTRODCTION

Beekeeping is a sustainable form of agriculture, which is beneficial to the environment and increases yield of food and forage crops through the pollination action of bees. It is a very long-standing practice among the farming communities of Ethiopia (Martin et al., 2012). It is a promising sideline farm activity for the rural households.

It directly and indirectly contributes to the income of households and the economy of the nation (MoARD, 2003).

Despite the long beekeeping tradition, having the highest bee density and being the leading honey producer as well as one of the largest beeswax exporting countries in Africa, the share of the apiculture subsector to the gross domestic product (GDP) has been negligible in Ethiopia. Productivity of the sub-sector has always been low, leading to low productivity of honey and relatively low export earnings. Thus, the beekeepers in particular and the country in general are not benefiting from the subsector as expected (Tadesse, 2001a).

As the country has immense natural resources for beekeeping activity, this sub sector has been devastated by various complicated constraints as clearly stated by Teklu et al. (2016). According to Chala et al. (2012), drought, decline in vegetation coverage and subsequent changes in natural environments, pests and predators, and indiscriminate applications of chemicals are causes for low honey productivity and improved beekeeping practices in the country. In line with the aformentioned impeding factors, there are also other major constraints that affect beekeeping subsector in Ethiopia such as: lack of beekeeping knowledge, shortage of skilled manpower, shortage of bee equipments, poor infrastructural development, and shortage of bee forage and lack of research extension (Kerealem, 2005).

According to Haftu et al. (2015), Ethiopia is recognized as top ten producers of honey globally which is clearly observed in the last few years with significant increment, however, the nation's output is still below 10 % of its production capacity, and this entails the existence of notable challenges strangulating the sector. As clearly stated by Tolera et al. (2014), the low yield of honey and other beekeeping products resulted from insufficient management practices and lack of adequate beekeeping training.

To put in place appropriate remedial interventions that would lead to enhanced productivity of the beekeeping subsector, understanding the prevailing major challenges, opportunities and future prospects of bee keeping and honey production is very vital. This necessitates the need for generating site specific database under specific production scenarios. In this regard, little research has been done so far to identity the overall smallholder beekeeping production constraints in Waghimara Zone (Abergell, Sekota and Gazgibala).

This study aims to fill this existing information gap. Hence, the objective of this study was to investigate the smallholder beekeeping production constraints as well as opportunities, and to suggest possible solutions for the identified constraints at their production environment.

MATERIALS AND METHODS

This study was conducted in three sites namely Abergell, Sekota and Gazgibala districts in Waghimara Zone of Amhara National Regional State, Ethiopia (Figure 1). The three districts were selected among the many districts due to their potential for honey production. Waghimara Zone is located 435km far from Bahir Dar, and 720 Km from Addis Ababa. The area is located at 12°N latitude and 38° E longitudes at an altitude of 500 to 3500 masl with annual rain fall of 150 to 700 mm which is an erratic type of rainfall. The annual average temperature ranges from 15 to 40°C. The soil type and climate are similar to those in many dry land areas of Ethiopia. Cattle, small ruminant, poultry and equines are the major livestock species kept in the Zone (unpublished report of WZLFRD, 2016/17). In the Waghimara Zone, there is huge potential of beekeeping, which is an integral part of the animal husbandry. It is a common culture and farming practice. Most of the beehives are virtually kept at backyards and modern beehives are common that farmers' have familiarized with its use nowadays (Table 1).

Study design

Crossectional study design was used for this assesement since the study was conducted in three districts having different agro-ecologies (Highland, Midland and Lowland). Thus, the data were collected from these three districts with different agro-ecology through data gathering instruments such as houeshold survey with semi-structured questionnaire, observation, keyinformant interveiw and focus group discussion. The design helped us to assess and make comparative analysis of the data collected from the three districts and nine peasant associations.

Sampling techniques and sample size

Purposive and systematic random sampling techniques was used for this study. From the total of 7 destricts in Waghimra Zone, three of them were selected purposely based on their agro-ecology and beekeeping potentials. Totally nine PAs (kebeles) were selected out of 67 PAs from the targeted districts once more by considering their agro-ecology. The sample household beekeepers were selected using Systematic (N^{th}) sampling technique that gives equal chance for the Nth repersentative samples from a list of farmers participated in beekeeping activity within the nine PAs. Thus, a single household respondent was used as sampling unit, and the total households included in this study were determined according to the formula given by Yamane (1967) with 95% confidence level of the households from the total beekeepers. 9 PAs were selected as follows:

$$n = \frac{N}{1 + N(e)^2}$$

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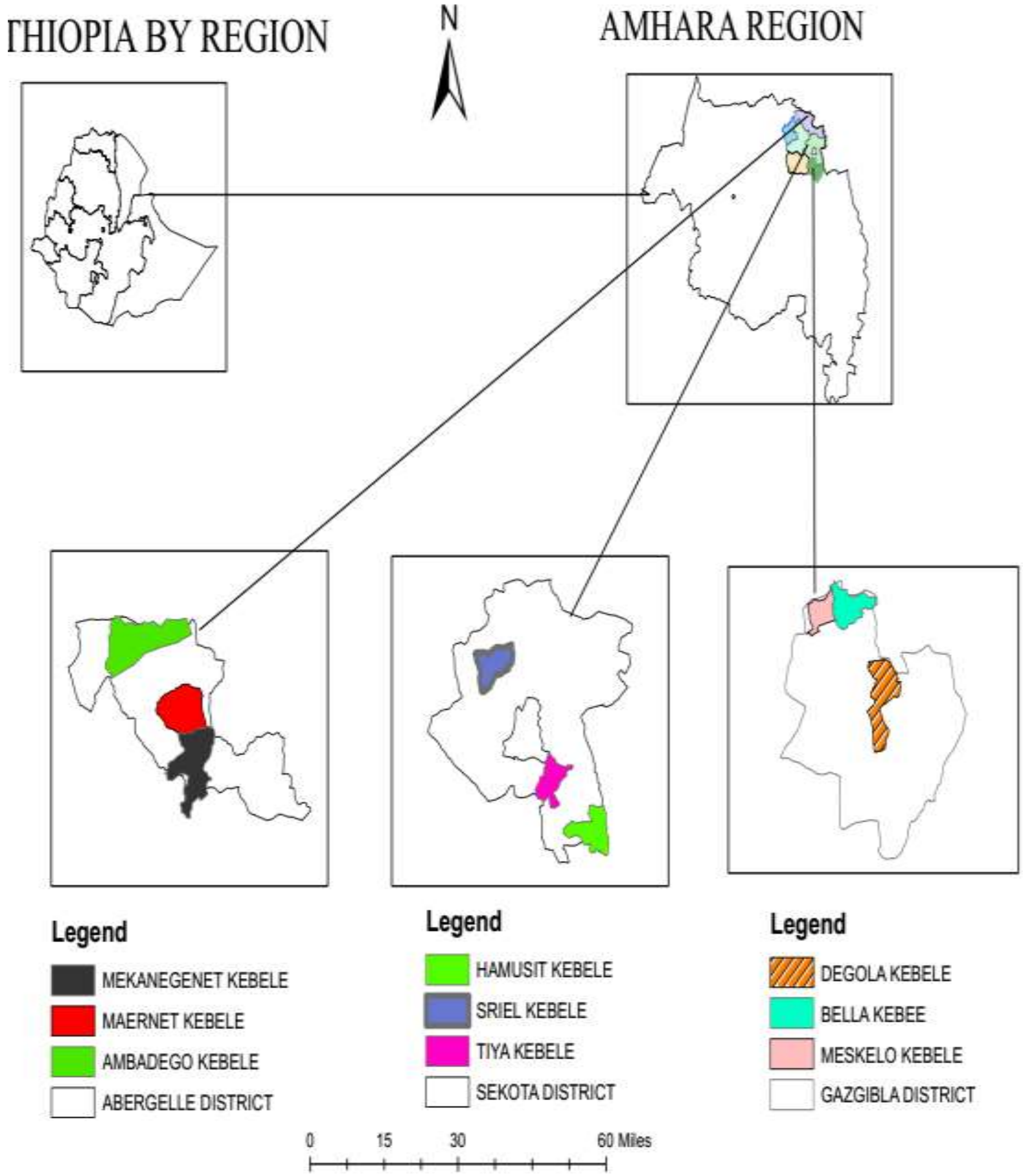

Figure 1. Map of the study area (Abergelle, Gazigibale and Sokata Districts).

Where:

n= Sample size, N= population size, e = the desired level of precision

Totally, 332 sample household beekeepers were determined from the three target districts and hence, the representative samples from each district (Sekota =165, Gazgibala =105 and Abergelle = 62) were also determined based on the number of beekeeper households in each district. In addition, sample size (N) was also tested by the formula recommended by Arsham (2005) as **N** = $0.25/SE^2$, where **N** is sample size, and SE is the standard error in order to validate its significance level.

Methods of data collection

In order to carry out this field survey study, discussion was undertaken initially with Waghimra Zone head of Livestock and Fisheries Resources Department, and bee experts of the selected districts. In addition, the researcher made a discussion with the heads of targeted districts Livestock and Fish Resources Head

Table 1. Waghimra Zone bee colony distribution by districts.

S/N	Districts	Area coverage		Bee resource		Bee colony per km^2(h/r)
		km^2(h/r)	Zonal share	Bee colony	Zonal share	
1	Sekota town	9375.96	1.07	1.544	2.02	0.165
2	Sekota	167156.29	19.03	21.702	28.37	0.130
3	Dehana	167631.40	19.09	12.105	15.82	0.072
4	Ziquala	170162.64	19.38	14.771	19.31	0.868
5	Abergelle	160658.64	18.29	3.393	4.44	0.021
6	Sehala	95077.15	10.83	8.106	10.60	0.085
7	Gazgibala	108133.16	12.31	14.874	19.44	0.138
Subtotal Zonal		878195.30	-	76.495	-	1.479

Source from: Waghimra Zone Animal and Fish Resources Department (2016).

Office, and bee experts for the selection of nine PAs. In the study, primary and secondary data were used to generate qualitative and quantitative information. Additionally, secondary data that has relevance to this study was collected from both published and unpublished sources.

Questionnaire

Primary data were collected from 332 household beekeepers using semi-structured questionnaire on demographic and socio-economic data, numbers of bee colonies, honey production potential, current practices and other beekeeping practices.

Focus group discussion (FGD)

FGD was undertaken with PAs leaders; development agents (DAs) and beekeeper farmers with best experience (30 participants, that is, 10 participants in one district) were purposely selected and participated in three districts. The FGD was carried out by means of guidelines (checklists) for participants and the discussion focused on: major challenges, opportunities and future prospects of bee keeping and honey production in the targeted districts.

Key informant interview

Key informant interview was under taken with three Zone bee and livestock experts, nine bee and livestock experts in 3 districts, 9 model beekeeper farmers and 3 beekeeping researchers. Totally, 24 key informants were interviewed in order to gather more of qualitative information deeply that was used to supplement, crosscheck and validate the data obtained through household survey.

Observation

Observation was anther instrument used in this study. From the total 4,250 beehives (traditional, modern and transitional), 366 sample hives were selected for field observation from 50 randomly selected households with in the 332 beekeeper sample household respondents. During observation, the researcher used guidelines on different beekeeping activities such as: framed and traditional hive placement, hives management, pest and predator, hive products, honeybee flora condition, dry season feeding and seasonal bee colony activities.

Method of data analysis

Quantitative data were organized and entered in to Microsoft Office Excel 2007, and analyzed using descriptative statistics and statisitical package for social sciences (SPSS) statistics version 20.

RESULTS AND DISCUSSION

Demographic characteristics of the respondents

As presented in Table 2 from the total sample, 93.4% were male and 6.6% female headed beekeeper, respectivelly. This result agrees with Haftu et al. (2015) who reported 93% of the interviewed beekeepers were male and only 7% were female headed beekeeper.

Similary,Taye et al. (2014) reported that 94.4% of the interviewed small scale beekeepers involved in honey value chain were males, where as 5.6% involved in honey value chain were females. Thus, it is posible to generalize that only few number of women participated in the beekeeping practice in the study area because there were different socio-cultural factors that impeded females to engage in beekeeping practice such as: beekeeping activities are mostly done at night; females can not afford the current bee colonies and beekeeping equipment price; females could not resist the agreesive behavior of bees. Almost half of 49.7% beekeeping participants lived in the high land agro-ecology whereas, the lowest number of beekeeping participants that is 18.7% lived in the low land areas, and the rest 36.6% of them lived in mid land agro-ecology.

The majority of beekeepers (59.9%) age ranges between 15 to 49 years. This indicates more than half of the beekeepers were under the productive age who can actively engage in beekeeping practice in study area.

Table 2. Demographic characteristics of the sample household beekeepers.

Category	Variable	Study area						Over all (N= 332)	
		HL (N=165)		ML (N=105)		LL (N=62)		F	Percentage (%)
		F	Percentage (%)	F	Percentage (%)	F	Percentage (%)		
Sex	Male	157	95.2	99	94.3	54	87.1	310	93.4
	Female	8	4.8	6	5.7	8	12.9	22	6.6
	Total	165	100	105	100	62	100	332	100
Age (years)	15-29 years	33	20.0	19	18.1	2	3.2	54	16.3
	30-49 years	75	45.5	48	45.7	22	35.5	145	43.7
	50-64 years	34	20.6	32	30.5	33	53.2	99	29.8
	>65 years	23	13.9	6	5.7	5	8.1	34	10.2
Marital status	Single	5	3.0	6	5.7	3	4.8	14	4.2
	Married	128	77.6	80	76.2	44	71.0	252	75.9
	Widowed	15	9.1	11	10.5	10	16.1	36	10.8
	Divorced	17	10.3	8	7.6	5	8.1	30	9.0
Educational status	Illiterate	91	55.2	53	50.5	27	43.5	171	51.5
	Reading and writing	30	18.2	18	17.1	11	17.7	59	17.8
	Primary (1-4)	30	18.2	20	19.0	14	22.6	64	19.3
	Junior (5-8)	10	6.1	10	9.5	6	9.7	26	7.8
	Secondary (9-12)	4	2.4	4	3.8	4	6.5	12	3.6
Experience in beekeeping activity (years)	1-5 years	38	23.0	24	22.9	15	24.2	77	23.2
	6-10 years	43	26.1	27	25.7	16	25.8	86	25.9
	11-20 years	40	24.2	25	23.8	15	24.2	80	24.1
	>21years	44	26.7	29	27.6	16	25.8	89	26.8
Family size	1-5 family	52	31.5	33	31.4	20	32.3	105	31.6
	6-10 family	108	65.5	67	63.8	42	67.7	217	65.4
	11-15 family	5	3.0	3	2.9	2	3.2	10	3.0
Position of household head in community	Political leader	67	40.6	43	40.9	25	40.3	135	40.7
	Spiritual leader	15	9.1	10	9.5	6	9.7	31	9.3

Table 2. Contd.

Elder	17	10.3	11	3.3	6	9.7	34	10.2
Community member	39	23.6	25	23.8	15	24.2	79	23.8
Kebele team leader	12	7.3	7	6.7	4	6.5	23	6.9
Kebele police	15	9.1	9	8.6	6	9.7	30	9.0

Source: Field survey, December-March, 2016/17, HL=highland, ML=midland, LL=lowland, N=number of respondents, F= frequency.

This result was comparable to the finding of Chala et al. (2012) who reported that average age of beekeeper in Gomma districts South West Ethiopia was 40.47 years.

As inicated in Table 2 from the total respondents, about 51.5% of them were illiterate, 19.3% attended primary education, 17.8% of them can read and write; 7.8% beekeepers attended junior education and the rest only 3.6% of beekeepers attended secondary education. This result was similar with the findings of Taye et al. (2014) that they reported 33.3% of beekeeper were illiterate. On the contrary, it vary from the findings of Tessega (2009) who reported that only 15.1 % were illiterate whereas 84.9% of them were literate. The difference might be due to in acessibilty of both formal and informal education in the Waghimara Zone esspicially in previous years.

Regarding respondents experience in beekeeping activity, 26.8% beekeepers have more than 21 years experience, 25.9% have from 6 to 10 years, 24.1% have between 11 to 20 years and the rest 23.2% of them had an experience of beekeeping from 1 to 5 years. The study of Chala et al. (2012) reported beekeepers had an average experience of beekeeping (5.66 years. Therefore, beekeepers in this study area had better experience of beekeeping than Chala's report.

As indicated in Table 2, 65.4 % of respondents had the family size of 6 to 10); 30.6 % them had family size of 1 to 5 and the rest 3 % of beekeepers had 11 to 15 family size. This indicated that the average family size of Waghimara Zone is so large that they need diversified source of income in addition to crop production and animal husbandry for generating income like beekeeping activities in order to improve farmers economic status. The current study was supported by Teklu et al. (2016) as they reported that the minimum and maximum family size of respondents were 5 and 7 respectively.

Socio-economic characteristic of the respondents

The major source of households income were from crop production which accounted for 27.7%, livestock production 23.8%, beekeeping activities 16.9% and irrigation which accounted 15.4% in descending order as shown in Table 3.

Therefore, beekeeping is the third ranking source of income for the beekeeper households in the study area. In relation to agro-ecology, beekeeping accounted for 21.8% source of income for households next to crop and livestock production which accounted for 30.5 and 26.1%, respectively in high land area of the study area and similarly beekeeping is the third ranking source of income in low land area which accounted for 16.1% next to crop and livestock production that accounted for 27.4 and 24.2%, respectively. On the other hand in the mid land area, beekeeping accounted only for 9.5% as source of income which is the lowest compare to high land and low land agro-ecologies as indicated in Table 3. In line with this result, Beyene and Verschuur (2014) reported that beekeeping ranks second source of income accounting for 26.27% share of household income.

Livestock and honeybee colonies holding of sampled households

The major types of livestock owned by respondents on average were goats 22.34, sheep 21.12, bee colony 13.11, poultry 9.46, cattle 6.03 and equines 1.76 per household in descending order as stated in Table 4. Regarding the number of bee colonies per household, the minimum and

Table 3. Socio-economic characteristics of the sample household in beekeeping.

Category	Variable	Study area: HL (N=165) F	Percentage (%)	ML (N=105) F	Percentage (%)	LL (N=62) F	Percentage (%)	Over all (N= 332) F	Percentage (%)
Source of income	Crop prod	52	31.5	23	21.9	17	27.4	92	27.7
	Livestock prod	43	26.1	21	20	15	24.2	79	23.8
	Beekeeping	36	21.8	10	9.5	10	16.1	56	16.9
	Irrigation	23	13.9	22	21	6	9.7	51	15.4
	Trade	7	4.2	15	14.3	5	8.1	27	8.1
	Service	4	2.4	14	13.3	4	6.5	22	6.6
	Fish prod	0	0	0	0	5	8.1	5	1.5
Major crop cultivation in the study area	Barley	42	25.5	23	21.9	2	3.2	67	20.2
	Sorghum	28	17	22	21	20	32.3	70	21.1
	Teff	22	13.3	21	20	16	25.8	59	17.8
	Pea	17	10.3	10	9.5	0	0	27	8.1
	Wheat	41	24.8	15	14.3	0	0	56	16.9
	Bean	15	9.1	14	13.3	0	0	29	8.7
	Oil crop	0	0	0	0	15	24.2	15	4.5
	Cowpea	0	0	0	0	9	14.5	9	2.7

Source: Field survey, December-March, 2016/17, HL=highland, ML=midland, LL=lowland, N=number of respondents, F= frequency.

the maximum bee colonies were 2 and 84, respectively with an average of 14.64 bee colonies. There is significant difference among beekeepers in having bee colonies. In supporting this finding, Yetimwork (2015) confirmed that beekeeper owned a maximum of 100 bee colonies and a minmum of 1 bee colony with an average bee colonies of 5.8 per household. Beekeepers revealed that they practiced beekeeping for getting cash income, consumption, dowry or gift and for breeding in descending order. This was similar with the findings of Nebiyu et al. (2013) who reported that the main purpose of beekeeping was for both income and household consumption depending on their importance (Table 4).

Traditional beehives

As indicated in Table 5, 68.4% of beekeepers used traditional hives for honey and bees wax production. This is due to lack of appropriate honey processing materials, lack of bee equipments and protective materials (like modern beehives, casting mold, frame wires, beeswax) and skilled manpower. This result was in agreement with the findings of Nebiyu et al. (2013) as 87.80% of beekeeping practices are covered by traditional beehives. These indicated beekeepers highly depend on traditional beehives than modern and transitional beehives. Most of the beekeepers (83.4%) constructed their own traditional beehives from local materials such as: comb hives from lumber and others from mud (which is a mixture of clay, cow dung and ash), different trees, like ‘Ekima’ *(Terminalia glaucescens*) and ‘bamboo’ (*Arundinaria alpine*). However, the rest 16.6 % beekeepers bought locally constructed beehives and some of them borrowed it from other beekeepers that had extra beehives.

As shown in Table 6, in the highland area, the maximum and the minimum traditional beehives per household were 50 and 2, respectively with

Table 4. Average livestock and honeybees number per household head.

Variable	N	Min	Max	Mean	S.E
Number of cattle per household head	332	2	15	6.03	0.188
Number of goat per household head	332	5	100	22.34	0.974
Number of sheep per household head	332	3	84	21.12	1.182
Number of pultry per household head	332	4	30	9.46	0.226
Number of bee colonies per household head	332	2	84	14.64	0.937
Number of equines per household head	332	1	5	1.76	0.058

Source: Field survey, December-March, 2016/17, SE=Standard Error, N=number of respondents.

Table 5. Number of beehive in the study area.

Type of beehives	Min	Max	Study area			
			HL N=165	ML N=105	LL N=62	Over all N=332
			Mean ±SE	Mean ±SE	Mean ±SE	Mean ±SE
Taditional	2	84	9.31±1.105	7.18±0.48	10.13±1.36	8.79±0.625
Transitional	1	8	2.29±0.302	2.04±0.285	1.83±0.306	2.11±0.182
Modern	1	21	3.78±0.637	3.78±0.44	7.38±1.09	4.38±0.414

N=number of respondents, SE=Standard Error, HL=highland, ML=midland, LL=lowland.

average number of 13.59±2.4 hives per household. In mid land area, there was high variation of beekeepers in having traditional beehives per households with the minimum and maximum of 2 and 84, respectively, which was more than other two agro-ecologies and the average traditional hive per household was 26.6±5.3. The average traditional hives per household in low land area was 16.4±4.9 which is more than the high land area and less than the mid land area whereas the minimum and maximum beehives per household were 2 and 63, respectively. There were significant differences on the practice of traditional beekeeping among the three agro-ecologies. In addition, traditional hives variability of having different shapes was attributed to the different climate conditions of the area and the beekeepers different honey production systems and techniques.

As shown in Table 7, the average numbers of traditional hives owned per household were 8.79±0.625 whereas the minimum and maximum hives per household were 2 and 84, respectively. The result indicated that there is no significant difference among beekeepers in Waghimara Zone. According to Addis et al. (2014) in and around Gonder, average numbers of traditional honeybee colony owned per household were 7.58 whereas the minimum and maximum beehives per household were 1 and 60. In relation to agro-ecology in the high land area, the average number of traditional hives per household was 9.3±1.1, in the midland 7.2±0.5 and in the lowland 10.13±1.4. Beekeepers have more traditional beehives per household in low land area than other agro-ecologies.

Transitional beehives

Beekeepers who owned transitional beehives were 7.8 % which was the smallest number as compared to traditional and modern beehives. As indicated in Table 7, the average numbers of transitional beehives owned per household was 2.11±0.18 whereas the minimum and maximum hives per household was 1 and 8, respectively. There were none significant difference on the practice of transitional beekeeping among the three agro-ecologies.

Modern beehives

Among the sampled beekeeper, 23.8% of them reported that they had modern beehives for their beekeeping activity. Similarly, Haftu et al. (2014) reported 8.5% of household beekeepers owned modern beehives in Hadya Zone. This indicates that the adoption rate of improved technology (modern beehives) is very low because of the cost of constructing and purchasing of modern beehives and due to lack of harvesting and processing equipment's to use modern beehives. In modern (frame hive), the average number of hives per household was 4.38. This was better than the findings of Tessega (2009) with the average number of modern hives per household (3.73). In low land area, beekeepers had relatively more number of modern beehives per household (7.38) than other two agro-ecologies due to beekeepers better awareness and good experience of getting high productivity of honey. Thus, the overall beekeepers practice of using modern

Table 6. Honeybee colonies holding per household in the study area.

Variable	Study area	N	Min	Max.	M±SE	S.D
Traditional hives colony only owned/households	HL	46	2	50	13.59±2.37	16.110
	ML	29	2	84	26.62±5.33	28.708
	LL	19	2	63	16.36±4.99	21.211
Transitional hive colony only owned/HH	HL	16	1	8	3.38±0.657	2.630
	ML	10	1	5	2.00±0.471	1.491
	LL	7	1	5	1.86±0.553	1.464
Framed hive colony only owned/HH	HL	24	1	15	3.71±0.724	3.544
	ML	15	2	15	5.87±1.032	3.998
	LL	10	1	21	8.00±2.006	6.342
Traditional and Transitional hive colony owned/households	HL	13	3	6	3.69±0.328	1.182
	ML	9	3	6	4.00±0.441	1.323
	LL	5	3	6	4.00±0.632	1.414
Traditional and Modern hive colony owned/households	HL	38	3	30	10.95±1.20	7.429
	ML	24	3	21	9.21±1.169	5.725
	LL	7	3	26	12.86±3.08	8.174
Transitional and Modern hive colony owned per households	HL	19	2	5	3.42±0.299	1.305
	ML	12	2	5	3.00±0.348	1.206
	LL	10	2	5	3.20±0.389	1.229
Traditional, Transitional and Modern hive colony owned/HH	HL	9	4	10	5.78±0.722	2.167
	ML	5	4	8	6.00±0.707	1.581
	LL	5	4	10	6.40±1.030	2.302

HL=highland, ML=midland, LL=lowland, N=number of respondents, S D= Standard deviation, S E =Standard Error.

Table 7. Honey yield, cost of beehives and bee colony and harvest frequency.

Variable	Min	Max	Study area: High Land N=165	Study area: Mid Land N=105	Study area: Low Land N=62	Over all N=332
			Mean ±SE	Mean ±SE	Mean ±SE	Mean ±SE
Traditional (kg)	5	50	8.90±0.63	10.53±0.82	12.89±1.02	10.16±0.46
Transitional (kg)	8	30	12.93±0.24	13.28±0.39	16.00±0.77	13.61±0.23
Modern hives (kg)	15	50	25.62±0.91	21.89±0.83	19.63±1.00	23.32±0.57
Price colonies (ETB)	500	2500	973.33±37.9	973.33±41.5	912.90±60.2	930.42±25.6
Prices of one transitional beehives (ETB)	100	120	105.45±0.61	105.90±0.85	103.39±0.87	105.21±0.44
Prices of one modern beehives (ETB)	1000	1500	1116.06±15.4	1228.57±17.5	1175.41±22.	1187.61±10.4
Frequency of honey harvest per annum of traditional hives	1	3	2.54±0.43	2.03±0.85	1.82±0.102	2.24±0.43
Frequency of honey harvest/yrs of transitional hives	1	2	1.33±0.037	1.27±0.43	1.10±0.038	1.27±0.024
Frequency of honey harvest per annum of modern hives	1	2	1.19±0.031	1.27±0.04	1.23±0.054	1.22±0.023

N=number of respondents, S E =Standard Error.

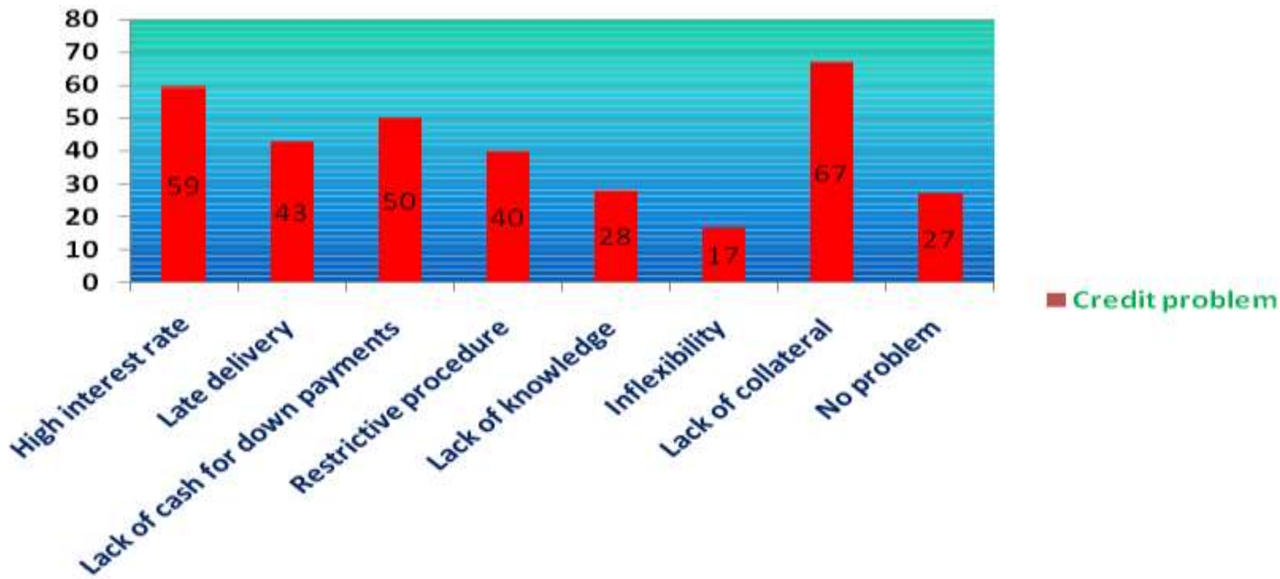

Figure 2. Credit problem for beekeeping activities in the study area (N=332).

beehives had a significant difference among the three agro ecologies (Table 7).

Challenges that hamper beekeeping practice and honey production

There were different major challenges of beekeeping practice and honey production in the study areas like; credit problems, pests and predators, lack of beekeeping equipments and protective materials, drought, indiscriminate applications of agro-chemicals etc.

Credit problems to carry out beekeeping practice

As illustrated in Figure 2, shortage of credit service to undertake beekeeping practice was ranked as priority problem in the study area. This is due to lack of collateral (20.2%), high interest rate (17.8%), lack of cash for down payments (15.1%), late delivery (13.1%), restricted procedure (12.1%), beekeepers lack of knowledge (8.4%) and inflexibility (5.1%) in descending order. For instance, from the total sampled beekeeper, only 8.2% of them reported, as they did not face problems in relation to credit sources whereas the majority 91.8% of them reported as they encountered the different challenges stated earlier. Beekeepers were not able to get collateral because the credit service was given for them in groups, which lack clear individual accountability, and hence it was mostly abused and miss used by some group members who got the credit service. This finding is similar with Tessega (2009) that he reported beekeepers have severe problem to get credit due to high interest rate, late delivery, and lack of cash for down payment, restrictive procedure, lack of knowledge, inflexibility and lack of collateral in descending order.

Pest and predators

As described by Desalegn (2001), Ethiopia, as one of the sub-tropical countries, the land is not only favorable to bees, but also for different kinds of honeybee pests and predators that are interacting with the life of honeybees. As reported in EEPD (2006), pests and predators cause a serious devastating damage on honeybee colony within short period of time and even overnight.

As indicated in Table 8, the major pests and predators, which harmed beekeeping practice and honey production in the study area were listed: The most important pests and predators in honey production are bee eater birds (1st), ants (2nd), wax moth (3rd), spiders (4th), lizards (5th), honey badger (6th), hama got or *mogoza* (7th), bee lice (8th), beetles (9th) and wasps (10th) as ranked in descending order by the respondents. In relation to this finding, Tewodros (2010) found that the most important pests and predators which harmed honeybees were wax moth, bee-eater birds, ants, and honey bag her, and lizards.

Similar finding was reported by Malede et al. (2015) as ants, honeybadgers, bee eater birds, waxmoth, spiders, termites, and snakes causing devastating damage to honey bee colonies and products within a short period of

Table 8. Major pest and predators challenging the beekeeping practice.

Variable	Study area									Over all (N=332)		
	HL (N=165)			ML(N=105)			LL (N=62)			F	%	Ranks
	F	%	Rank				F	%	Ranks			
Ants	24	14.5	2nd	13	12.4	2nd	10	16.1	1st	47	14.2	2nd
Wax moth	23	13.9	3rd	12	11.4	3rd	9	14.5	2nd	44	13.3	3rd
Bee lice	9	5.5	9th	9	8.8	6th	7	11.3	4th	25	7.5	6th
Spiders	20	12.1	5th	12	11.4	3rd	4	6.5	6th	36	10.8	4th
Bees eater birds	27	16.4	1st	15	14.3	1st	9	14.5	2nd	51	15.4	1st
Hama got (mogoza)	18	10.9	6th	11	10.5	4th	4	6.5	6th	33	9.9	6th
Lizards	21	12.7	4th	10	9.5	5th	5	8.1	5th	36	10.8	4th
Wasps	6	3.6	10th	4	3.8	8th	3	4.8	7th	13	3.9	8th
Beetles	3	1.8	11th	7	6.7	7th	4	6.5	6th	14	4.2	7th
Honey badger (Death head hawks month)	14	8.5	8th	12	11.4	3rd	8	12.9	3rd	34	10.2	5th

%= percentage; F= Frequency.
Source: Field survey, December-March, 2016/17.

time. This result was also supported by Teklu et al. (2016) as they reported that the major problems of beekeeping practice in the area are honeybee enemies such as ants, honey badgers, birds and small hive beetles which accounted for 20% of the total honey production loss annually.

Agro ecologically, bees eater birds were identified as number one enemies of honey bees in the high land and in the mid land agro-ecologies whereas they were identified as the second major enemies in the low land agro-ecology because in the low land areas ants were the major enemies of honeybees. The second major identified pests, which harmed the honeybees in the study area, were ants. Agroecologically, ants were identified as the second major enemies of pests in the high land and mid land agro-ecologies; however, they are the 1st major enemies of honeybees in the low land areas. This result also supported by Chala et al. (2012) as they reported beekeepers witnessed that bee colonies suffered from ants which results in death of adult honey bees in the hive and absconding of bee colony.

Moreover, wax moth was ranked as the third major type of pests that harmed honeybees because beekeepers did not conduct continuous follow up and removing of the old combs affected by wax moth larva. Additionally, spider and lizards were ranked as the fourth major pests and predators, which attack the honeybees. Lizards were ranked as the fourth major enemies of honeybees in the high land areas whereas they were identified as the fifth major predators of honeybees in the mid land and lowland areas. On the other hand, spiders were identified as the third major pests which harmed the honeybees in the mid land; however, they were ranked as the fifth and sixth major enemies of honeybees in the highland and low land areas, respectively as indicated in Table 8.

In general, bee-eater birds, ants and wax moth were the first, second and the third major enemies of honeybees in the study area, respectively. In order to address these challenges, beekeepers used different techniques to protect the major pests and predators. For instance, beekeepers protect bee-eater birds by placing gum plants where the birds rest near the apiary; killing the birds using smoke at their nest and by chasing away the birds at times when they visit the apiary in morning and afternoon times when birds mostly visit apiaries.

Beekeepers used the gums of *Tapinanthus aurantias* which is a type of shrub in order to protect bee's eater birds. To protect ants, most of the beekeepers used dung, fresh ash, mud, malatione and hot water, burning the ants with water, destroying ants' nests, and pouring engine oil around the beehives stands. Additionally, beekeepers protected wax's moth by applying different techniques such as: cleaning apiary, removing the old comb, strengthening the bee colony with giving supplementary feeding, fumigation with the seed of Noug (*Guizotia abyssinica*) and narrowing the entrance of beehives.

Honeybee poisoning plants

There were different poisoning plant species like: trees, shrubs, herbs and field crops that have a negative effect on honeybees, beehive products and humans. Beekeepers identified 4 major tree species, 6 species of shrubs, 2 cultivated field crop types and 1herbs as poisoning plant species in their surroundings as indicated in Table 9. In line with this study, Kerealem (2005) reported that nectar or pollen of poisonous plants was toxic to honeybees, and the honeys produced from their

Table 9. Honeybee posing plant in the study areas.

Name of the plant species		Floral type	Source of pollen and nectar	Flowering calendar (month)	Effect on		
Local name (Agewugna)	Scientific name				Bees	Beehive products	Humans
Neem tree	*Azadirachta*	Trees	-	-	X	-	-
Yeferenj suf	*Heliantnus annus*	Field crop	Pol/ Nec	September	X	-	-
Dikuan tilla	*Verbena officinalis*	Herbs	Pol/Nec	July	X	-	-
Ater	*Pisum sativum*	Field crop	-	September	X	-	-
Kichib	*Euphorbia tirucalli*	Shrubs	-	Year round	-	X	X
Kalkalda	*Euphorbia Spp.*	Shrubs	-	Year round	-	X	X
Acacha	*Acacia saligna*	Trees	-	-	X	-	-
Chiret	*Agave sisalana*	Shrubs	Pol/Nec	September	-	X	X
Kulqual.	*Euphorbia Spp*	Shrubs	Pol/Nec	March	-	X	X
Eret	*Oleo berhana*	Shrubs	-	September to Oct	-	X	-
Azo harege	*Clematis hirusta*	Shrubs	-	March	X	-	-
Shola	*Ficus*	Trees	-	January-February	X	-	-
Shisha	*Boscia anquistifolia*	Trees	Pol/Nec	April	X	-	-

Source: Field survey, December-March, 2016/17.

nectar were toxic to humans. Based on his finding, he recommended that removing those poisoning plants around apiary site, developing improved and local bee forage species were solutions to address the problem. The result of this study agrees with previous findings of Yetimwork et al. (2015) as they reported that about 43.6% of experienced beekeepers identify the major poisonous plants in their surroundings. Plants like *akacha (Acacia saligna), qnchb* (*Euphorbia species*); limo or false *neem* (*Melia azedarach)* and *neem* (*Azadirachta indica)* are identified as poisons. This result is supported by Chala et al. (2012) as they reported that only experienced beekeepers listed few poisons plants in their locality. These can be plants whose nectar or pollen is toxic to the bees themselves, and those in which the honey produced from their nectar are toxic to humans.

Indiscriminate utilization of agro-chemicals

FAO (2012) reported that the present increasing use of pesticides and herbicides is severely threatening bee colonies implying conflicts of crop and honey production. The use of chemicals and pesticides for crop pests, weeds, Tsetse fly, mosquitoes and household pests control brings the possibility of damaging the delicate equilibrium in the colony, as well as the contamination of hive product as reported in EFSA (2012). The promotion of some agricultural inputs such as pesticides and herbicides for cereal crop production as well as the use of deadly chemicals for malaria eradication program have substantially reduced honey production in the study area. As shown in Table 10, most of the beekeeper (62.7%) reported as they used agro-chemicals for crop pest protection, to control weeds, malaria, external parasites and house pests which bring the real possibility of damaging the delicate equilibrium in the bee colony and contamination of beehive products. Large number of respondents (39.5 %) used agro-chemicals for the purpose of controlling weeds, 24.4% of them for malaria control, 20.8% for crops pest control, and the rest 15.4% of beekeepers used agro-chemicals for controlling external parasites. Relatively, large number of beekeeper reported that they used agro-chemicals for controlling weeds; however, in the study area there is large number of family size (6.57 per household) that could be used as a source of family labour to control weeds instead of

Table 10. Use of agro-chemicals (pesticides and herbicides) in the study area.

Category	Variable	Frequency of the respondents (N=332) N (%)
Use of agro-chemicals (Pesticides and Herbicides)		
Do you use agro-chemicals	Yes	208 (62.7)
	No	124 (37.3)
Months of using agro-chemicals	July to August	168 (50.6)
	September to October	29 (8.7)
	November to December	35 (10.5)
	January to February	40 (12.0)
	March to April	30 (9.0)
	May to June	30 (9.0)
Purpose of using agro-chemicals	Weeds	131(39.5)
	Crops pest control	69 (20.8)
	Malaria	81(24.4)
	External parasite	51(15.4)
Types of agro-chemicals use in the study area	2.4-D	106 (31.9)
	Diazole	59 (17.8)
	Malathion	37(11.1)
	Sevin	22 (6.6)
	DDT	46 (13.9)
	Deltamethrin	62 (18.7)
Affect honeybee by agro-chemicals	Yes	202 (60.8)
	No	130 (39.2)
Impacts of chemicals on honeybees and beekeepers	Dead of bees	138 (41.6)
	Absconding	129 (38.9)
	Low beehive products	65 (19.6)
Honeybees lost due to use of chemicals in 5 years	One up to five bee colonies	141 (42.5)
	6-10 bee colonies	68 (20.5)
	11-15 bees colonies	43 (13.0)
	16-20 bee colonies	49 (14.8)
	> 21 bee colonies	31 (9.3)
Estimated honey production (kg) per years	10-20 kg of crude honey	128 (38.6)
	21-40 kg crude honey	95 (28.6)
	41-60 kg crude honey	64 (19.3)
	>61 kg crude honey	45(13.6)
Estimated in prices (ETB) per years	1.000-2,000 ETB	122 (36.7)
	2.001-4,000 ETB	106 (31.9)
	4.001-6,000 ETB	57(17.2)
	>6.001 ETB	47(14.2)

Source: Field survey, December-March, 2016/17, N= number of sampled respondents.

using agro- chemicals, which has a strong negative impact on the honeybee colonies, and honey production in the study area.

As indicated in Table 9, different types of agro-chemicals used by farmers such as 2, 4-D, Diazole, Malathion, Sevin, DDT and Deltamethrin. This result agrees with previous findings, (Sintayehu, 2016) as he reported different pesticides and herbicides used by farmers like: Malathion, Sevin, DDT, 2-4 D, Acetone, Roundup/Glyphosate, Topic, and Palace are commonly used separately or in combination. This result is similar to other studies like Kerealem et al. (2009) who reported that the spraying herbicides destroying bee forage like herbs and shrubs which is used as sources of bee forage. The use of pesticides that kill bees and herbicides are not only toxic to bee colonies but destroy many plants that are valuable to bees as sources of pollen and nectar.

Impact of the utilization of agro-chemicals on beekeeping practice and honey production

According to Bekele (2015), the use of pesticides and herbicides for crop pests, weeds, *Tsetse* fly, mosquitoes and household pests control brings into focus the real possibility of damaging the delicate equilibrium in the colony, as well as the contamination of hive products. Among the various kinds of chemicals, only insecticides and herbicides are now major problems to the beekeepers especially chemicals used for crop protection are the main pesticides that kill the honeybees. Most of the sampled beekeepers (60.8 %) reported that they had awareness on the negative impact of using agro-chemicals on honeybees and honey production whereas the rest (39.2 %) of beekeepers reported that agro-chemicals do not affect honey bees and honey production. However, in the study area, the overall average estimated honeybee colony and honey production lost per household/ year due to use of agro-chemicals were 5.1 bee colony and 31.9 kg of crude honey respectively. The estimated honey production lost in price per household in a year due to the indiscriminate application of agro-chemicals was 4,125.37 ETB as shown in Table 10. This study is similar with previous evaluation in that, due to agro- chemicals aplication, some beekeepers lost their colonies totally as discribed by Taye et al. (2014).

High cost and scarcity of beekeeping equipments and accessories

98.19 % of the beekeepers in the study area reported as there was shortage of beekeeping equipments and protective materials such as: smokers, protective materials (veil, gloves, boots, and overall), casting mold, honey extractor, bee brush, honey presser, water sprayer, frame wire, chisel, un capping of fork, queen excluder, embedded etc, in descending order. This result was similar to Edessa (2005) who reported that an introduction of improved beekeeping technology to rural communities are beyond the affording power of beekeepers, and they are not easily availabile even for those who can afford to it. Similarly, Taye et al. (2014) stated that, some of the bee equipments such as modern beehives, wax printers and honey extractors are very expensive and thus, farmers could not afford to purchase and use these equipment's. Based on the sampled respondents, the distribution of beekeeping equipments was relatively better in the mid land area than the low land and the high land areas. This is due to the presence of different non-governmental organizations (NGOs) in the area, it is also the center of Sekota Dry Land Agriculture Research Center that works as a research in queen rearing practice for distributing to the beekeepers.

Major challenges that hinder beekeeping practice and honey production

As indicated in Table 11, the major challenges and problems that hider beekeeping practices and honey production were pests and predators, drought, agro-chemical spraying (herbicides and pesticides), poor farmers' awareness for adopting technologies, and lack of bee forage associated with deforestation. In addition, shortage of beekeeping equipments and materials; shortage of water' lack of knowledge in bee management, high cost of modern beehives and shortage of accessories, absconding, hive product adulteration, lack of training/skills of beekeeping, shortage of honeybee colonies; swarming; honeybee disease; death of bee colonies in case of unknown disease; illegal colony marketing; and poor extension services related to beekeeping.

This result agrees with the report of Malade et al. (2015) that stated various constraints and challenges that hamper beekeeping and honey production sub sector. Some of them are shortage of bee forage, application of chemicals, pest and predator (ants, birds, spiders, honey badger, termite, snake, and wax moth), lack of rainfall, absence of policy in apiculture and others. Similarly, Kerealem et al. (2009) found that shortage of bee forage, threat of pesticide, honeybee pest and predators, poor infrastructure development, and shortage of bee equipments, which were reported as the major beekeeping constraints in Amhara National Regional State.

Agro ecologically, the first major challenges that impeded beekeeping practices and honey production in the study area were pests and predators which attacked honeybee colonies. It was identified as the first major

Table 11. Major challenges that hinder beekeeping practice and honey production.

Variable	Study area									Over all (N=332)		
	Highland (N=165)			Midland (N=105)			Lowland (N=62)			N	Percentage (%)	Rank
	N	Percentage (%)	Rank	N	Percentage (%)	Rank	N	Percentage (%)	Rank			
Lack of bee forage associated with deforestation	11	6.7	3rd	5	4.8	4th	3	4.8	2nd	19	5.7	4th
Shortage of beekeeping equipment and materials	8	4.8	6th	5	4.8	4th	3	4.8	2nd	16	4.8	5th
Pests and predators	16	9.9	1st	8	7.6	2nd	4	6.5	1st	28	8.4	1st
Absconding	7	4.2	7th	4	3.8	5th	3	4.8	2nd	14	4.2	7th
Drought	12	7.3	2nd	10	9.5	1st	4	6.5	1st	26	7.8	2nd
Shortage of water	7	4.2	7th	5	4.8	4th	3	4.8	2nd	15	4.5	6th
Pesticides and Herbicides Application	10	6.1	4th	7	6.7	3rd	4	6.5	1st	21	6.3	3rd
Swarming	5	3.0	9th	4	3.8	5th	2	3.2	3rd	11	3.3	10th
Lack of knowledge (in bee management)	7	4.2	7th	4	3.8	5th	3	4.8	2nd	14	4.2	7th
Marketing problems	2	1.2	12th	3	2.9	6th	2	3.2	3rd	7	2.1	14th
Lack of training/skills of beekeeper	7	4.2	7th	4	3.8	5th	1	1.6	4th	12	3.6	9th
Shortage of bee wax's(pure) for modern beehives	4	2.4	10th	4	3.8	5th	1	1.6	4th	9	2.7	12th
Shortage of honey bee colonies	5	3.0	9th	4	3.8	5th	2	3.2	3rd	11	3.3	10th
Death of bee colonies (due to mill and *michi)*	4	2.4	10th	4	3.8	5th	2	3.2	3rd	10	3.0	11th
Salle of honey with bee wax's any honey	3	1.8	11th	3	2.9	6th	3	4.8	2nd	9	2.7	12th
High prices cost of modern beehives and shortage accessory	9	5.5	5th	3	2.9	6th	2	3.2	3rd	14	4.2	7th
Poor extension services related to beekeeping	5	3.0	9th	3	2.9	6th	2	3.2	3rd	10	3.0	11th
Lack of business supports services	2	1.2	11th	2	1.9	7th	2	3.2	3rd	6	1.8	15th
Deforestation	7	4.2	7th	4	3.8	5th	2	3.2	3rd	13	3.9	8th
Poor design of transitional beehive	4	2.4	10th	2	1.9	7th	2	3.2	3rd	8	2.4	13th
Illegal colony marketing	6	3.6	8th	3	2.9	6th	1	1.6	4th	10	3.0	11th
Poor farmers a wariness for adopting technologies	11	6.7	3rd	7	6.7	3rd	3	4.8	2nd	21	6.3	3rd
Hive product adulteration	6	3.6	8th	4	3.8	5th	2	3.2	3rd	12	3.6	9th
Honey bee diseases	6	3.6	8th	3	2.9	6th	2	3.2	3rd	11	3.3	10th

Source: Field survey, December-March, 2016/17, N= number of sampled respondents.

Table 12. Classification of the major honeybee plant species in the study area.

Honeybee plant species	Frequency	Percentage (%)	Ranks
Trees	26	27.4	1st
Shrubs	24	25.3	2nd
Herbs	11	11.6	4th
Grass	5	5.2	5th
Filed crops	18	18.9	3rd
Horticulture crops	11	11.6	4th
Overall	95	100.0	-

Source: Field survey, December-March, 2016/17.

challenge in the high land and low land agro-ecologies whereas it was identified as the second in mid land agro-ecology rather drought was ranked as the first major challenge in the mid land areas. On average, throughout the three agro-ecologies, drought were identified and ranked as the second major challenge of beekeeping practice and honey production in the study areas. However, this challenge was identified as the 1st impending factor of beekeeping practice in the low land and the mid land areas whereas it was the second in the highland areas in relation to agro-ecology. This result is similar to Teklu et al. (2016) as they reported that pest and predators, shortage of bee colony, lack of training/skill of beekeeper, high cost of bee hives, shortage of bee forage, lack of business support services, marketing, beekeeping materials/ equipments, chemical application, absconding, swarming, diseases and storage facility/post-harvest handling, etc, in descending order.

The sample beekeepers confirmed, as drought was a serious challenge in the low land area than other two agro-ecologies. Recurrent drought was observed in these areas from 2 to 3 times within each five years due to deforestation, caused by rapid population growth and overgrazing. The third major challenge which impeded the practice of beekeeping and honey production in the study area, was using pesticides and herbicides as indicated in Table 13. In relation to agro-ecology, agro-chemicals were highly used by farmers in the low land areas than the high land and mid land areas because farmers owned large farmland size and hence they used more herbicides to control weeds. They also used pesticides to control pests such as malaria, external parasites of sheep and goats, and to prevent crop pests.

Shortage of bee forage

Shortage of bee forage leads a devastating problem that retards the production and productivity of honeybee colonies especially during the drought period. This constraint is highly associated with lack of rainfall and insufficient availability of bee forage as stated by Malede et al. *(*2015). Taye et al. (2014) also justified that bee forage problem is directly related with deforestation of forest coverage for timber making, construction, firewood and expansion of agricultural lands, which occur especially during the dry season, and beekeepers migrate their bee colonies from their area to other for searching bee forage. Moreover, there are environmental changes in Ethiopia in terms of erratic rainfall patterns and deforestation that worsen the problems beekeeping sub-sector as reported in Oxfam (2008).

Absconding and migration

Absconding is anthor swarm activities pattern which is not a reproductive mechanism. The colony in its selected site subsequently experienec difficulties with ants or other pests, due to lack of water or even lack of food. Consquentily bees leave their site for another or abandoned their hives at any season of the year for different reasons such as: lack of forage, incidenec of pest and preditors, during havesting, sanitation problem, bad weather condition and bee diseases as stated by Chala et al. (2012).

Potential of honeybee plant flora and their flowering calendar

As shown in Table 12, sampled respondents identified 95 species major honey bee plant species such as: trees, shrubs, field crops, herbs and horticulture crops in their environment. Among this honeybee flora; 26 species of tree, 24 species shrubs, 18 species of field crop, 11 herbs and field and 5 grass species have been found to be the dominant honey bee plants of the study area in a descending order.

The major sources of honeybee plants in terms of preference by honeybees and abundance from the tree

Table 13. List of honeybee plant species and flowering time.

Name of the honeybee plant species in the study area		Floral type	Source of (Pollen and Nectar)	Flowering calendar (month)
Local name (Agewugna)	**Scientific name**			
Tsalwa	Acacia asak	Trees	Pol/ Nec	April
Key Girar	Acacia seyal	Trees	Pol/Nec	May
Abiqa	Acacia tortolis	Trees	Pol/Nec	May
Firtata	Adanonia digitata	Trees	Pol/Nec	June
Sibqana	Albezia amara	Trees	Pol/Nec	May
Goza	Balanite aeqyptica	Trees	Pol/Nec	April
Shisha	Boscia anquistifolia	Trees	Pol/Nec	April
Wanza	Cordial Africana	Trees	Pol/Nec	May
Bahirzaf	Eucalyptus camaldlensis	Trees	Pol/Nec	May
Qundoberberia	Schinus molle	Trees	Pol/Nec	March
Dokima	Syzygium guinecs	Trees	Pol/Nec	April
Ekima	Terminalia glaucescens	Trees	Pol/Nec	April
Giba	Ziziphus spinachristi	Trees	Pol/Nec	September
Bisana	Croton macrostachyus	Trees	-	January to Feb
Sesbania	Sesbania sesban	Trees	-	January
Wareka	Ficus vasta	Trees	-	March
Endodo	Phytolacca dodecandra	Trees	-	January-March
Muja	-	Trees	-	August
Shola	Ficus	Trees	-	January-Feb
Koso	Hagenia abyssinica	Trees	-	October-Nov
Kitkita	Dodonea angustifolia	Trees	Pol/ Nec	Year round
Degta	Calpurnia aurea	Trees	-	October-Dece
Kokoba	Maytenus senegalensi	Trees	-	Nov-January
Girawa	Vernonia Spp.	Trees	-	Nov-January
Bisana	Croton macrostachy	Trees	-	March –April
Tid	Juniperus procera	Trees	-	Janua-March
Echileqana	Acacia brevispica	Shrubs	Pol/Nec	May
Gumarna	Acacia mellifera	Shrubs	Pol/Nec	May
Chiret	Agave sisalana	Shrubs	Pol/Nec	September
Malqoza	Asparagus Spp.	Shrubs	Pol/Nec	March
Mentese	Grandiflorum	Shrubs	Pol/Nec	July
Kushele	Echinops Spp.	Shrubs	Nectar	Spetember
Dedeho	Euclea shoperi	Shrubs	Pol/Nec	March
Kulqual.	Euphorbia Spp	Shrubs	Pol/Nec	March
Matta	Grewia villosa	Shrubs	Pol/Nec	July
Bahir kulqual	Opunitia Spp.	Shrubs	Pollen	June
Kentaftafa	Pterolobium stellatum	Shrubs	Pol/Nec	March
Enbacho	Rumex nervosus	Shrubs	Pol/Nec	March
Girawa	Vernonia Spp.	Shrubs	Nectar	April
Eret	Oleo berhana	Shrubs	-	Sept – Oct
Agam	Carissa edulis	Shrubs	-	Oct to Dec
Beles	Opuntia Spp.	Shrubs	-	April to June
Kalkalda	Euphorbia Spp.	Shrubs	-	Year round
Sensel	Justicia shimeriana	Shrubs	Pol/Nec	August
Gumero	Capparis micrantha	Shrubs	Pol/Nec	June
Teketila	Tapinanthus aurantias	Shrubs	Pol/Nec	September
Kichib	Euphorbia tirucalli	Shrubs	-	Year round
Azo harege	Clematis hirusta	Shrubs	-	March

Table 13. Contd.

Lucina	Leucaena lecucocephala	Shrubs	Pol/Nec	August-Sept.
Terilucern	Chamaecytisus profilererus	Shrubs	-	Feb/June-July
Gomen zer	Brassica Spp,	Field crops	Pol/ Nec	September
Noug	Guizotia abyssinica	Field crops	Pol/ Nec	September
Selit	Sesamum indicum	Field crops	Pol/ Nec	August
Mashila	Sorghum bicolor	Field crops	Pol/ Nec	September
Bekiela	Vicia faba	Field crops	Pol/ Nec	September
Bekolo	Zea mays	Field crops	Pol/ Nec	August
Berbere	Capsicum annuum	Field crops	-	Sept-Nov
Telba	Linuum vsitatissiumum	Field crops	-	Sept-Oct
Zikakibe	Ocumum basilicum	Field crops	-	October
Duba	Pumpkin	Field crops	-	July-Oct
Abish	Trigonella foeniculum	Field crops	-	December
Tosign	Thymus schimperi	Field crops	-	July-Sept
Tenadam	Ruta chalepensis	Field crops	-	October
Meser	Lens culiaris	Field crops	-	January
Shembera	Cicer artietinum	Field crops	-	November
Shinkhrt	Allium cepa	Field crops	-	Year round
Teamatim	Lycopersicon esculentum	Field crops	Pol/Nec	Jun-Sept.
Teff	Teff ergoistatis	Field crops	-	Sept-Oct
Aluma	Achyranthus Spp.	Herbs	Pol/Nec	September
Adey ababa	Bidens Spp.	Herbs	Pol/Nec	August
Tej matebia	Hypoestes trifolia	Herbs	Pol/Nec	September
Aba timara	Ocimum bacilicum	Herbs	Pol/Nec	August
Dikuan tilla	Verbena officinalis	Herbs	Pol/Nec	July
Maget	Trifolium Spp.	Herbs	Nectar	August
Kessie	Lippie adoensis	Herbs	-	September
Gishra		Herbs	-	July-Sept
Feto	Lepidium sativan	Herbs	Pol/Nec	September
Yefyel	Plectranthus Spp.	Herbs	Pol/Nec	August
Tirunba	Zantadescha Spp	Herbs	Pol/Nec	September
Serdo	Cynodon dactylon	Grass	Pollen	August
Wariat	Digitaria abyssinica	Grass	Pollen	August
Senbelet	Hyparrhenia rufa	Grass	Pollen	August
Sar	Unidentified grass Spp	Grass	Pollen	August
Gorteb	Plantago Spp.	Grass	Pollen	August
Mango	Mangifera indica	Horticultural crops	Pol/ Nec	April
Avocado	Persea American	Horticultural crops	-	Sept.-Dec
Banana	Musa paradisca	Horticultural crops	-	Sept.- Oct
Muze	Mush x paradisiacal	Horticultural crops	-	Year round
Papaya	Carica papaya	Horticultural crops	-	February
Coffee	Buna	Horticultural crops	-	April-June
Lemon	Citrus Spp.	Horticultural crops	-	Sept-Oct
Cotton	Gossypium	Horticultural crops	-	Sept-Oct

Table 13. Contd.

Gesho	Rhamnus prinoides L.	Horticultural crops	Pol/Nec	Jun-July
Zeyitun	Psidium guijava	Horticultural crops	Pol/Nec	March

species were *Acacia asak, Terminalia glaucescens, Acacia seyal and Acacia tortolis*. In relation to shrubs like: *Grandiflorum, Acacia mellifera, Asparagus Spp., and Euclea shoperi* in descending order. Some of the field crop species for honey bee flora were *Sorghum bicolor, Zea mays, Ocumum basilicum, Guizotia abyssinica and Sesamum*. Other sources of honeybee forage were herbs like: *Hypoestes trifolia, Ocimum bacilicum, Bidens Spp.and Verbena officinalis,* etc, and other honeybee flora species types were grasses like *Cyndo dactylon, Hyparrhenia rufa, (Unidentified grass Spp.), Plantago Spp and Digitaria abyssinica*, in descending order as indicated in Table 13.

The respondents reported as all grass species provide only pollen whereas all tree, shrubs, herbs, field crops species identified provided both source of pollen and nectar for honeybee in their environment. This study was strongly agreed to by Abebe et al. (2014) who reported *A. tortolis, O. bacilicum, Becium grandiflorum, H. trifolia, Sorghum bicolor, Bidens spp., Guizotia abyssinica, Echinops Spp., Vernonia Spp.,Grewia bicolor, Brassica spp., Eucalyptus camaldlensis, Aloe berhana, Un-Identified spp., Acacia asak, Ziziphus spinacristi, Opuntia Spp., Acacia mellifera, Euphorbia Spp.* and *Acacia seyal* have been found to be the dominant honey bee plants of the study area.

In order to maximize honey production, the availability of potential flowering plants is the main parameter for an area to be considered as potential for beekeeping practice and honey production; however, the honeybee flora is diminishing from time to time in the study area due to the expansion of agriculture deforestation, soil erosion and rapid population growth. This finding agrees with the result of BOA (2016) that reported as the regions vegetation cover is quite small especially the high forest area was not greater than 5 % and hence in the region, there is high degradation of natural resource base, which demands strong conservation and rehabilitation efforts.

Major opportunities and potentials of honeybee production in the study area

There are many opportunities to increase the over all production of beekeeping in Waghimara Zone because the area has many opportunities and potentials for the production of honey. Some of these opportunities are the experience and the indigenous knowledge of the beekeepers, high demand of honey in the area and the attention given for this subsector. In addition, conducive agro-ecology and adaptation of the local honeybee races (*Apis mellifera monticola)* to the recurrent drought due to low tendency for reproductive swarming and migration are also important opportunities.

As indicated in Table 14, the first major opportunities and potentials of beekeeping practice and honey production in the study area was abundance of huge number honeybee colonies. Secondly, the availability of potential flowering plants like: *A. asak, T. glaucescens, Grandiflorum, A. mellifera, Asparagus, H. trifolia, O. bacilicun, Bidens spp, S. biccolor, Zeamays and O. basilicum*. Another major opportunity was high market demand for beehive products in the domestic market. High market price of honey triggered farmers to engage in beekeeping practice. The fifth ranked potential and opportunity for beekeeping practice and honey production was high soil, water conservation, water shed practice and area enclosure. This created good opportunity for the growth of bee plant flora especially in the high land and mid land agro-ecologies. Sampled beekeepers reported that water shed practice and area enclosure could be used as job opportunities for organized youth groups to engage in beekeeping practice. The sixth ranked major opportunity and potential of beekeeping practice and honey production in study area was its socio-economic value because honey is used for different socio-economic values such as source of income to cover various household expenditures; for medicine, consumption, different cultural and ritual ceremony.

The seventh ranked major opportunity and potential of beekeeping practice was presence of government organisations (GOs) and NGOs who were involved in beekeeping practice, for instance, they supplied credit service in cash, beehive, bee colony, bee equipments and they gave short term training on beekeeping practice especially to the adult females and youth. The eighth ranked major opportunity was the availability of micro financial institutions for small-scale credit facility like the (ACSI) which give credit service to farmers in form of cash.

In addition to this, beekeeper had their own indigenous knowledge like: their own swarm controlling mechanisms providing supplementary feed at times of drought season. There is also the development of infrastructures in the

Table 14. Major opportunities of beekeeping to identify by the respondents.

Variable	Study area									Over all (N-332)		
	HL (N=165)			ML(N=105)			LL (N=62)					
	Frequency	Percentage (%)	Ran	Frequency	Percentage (%)	Ran	Frequency	Percentage (%)	Rank	Frequency	Percentage (%)	Ranks
Abundance of huge number of honeybee colonies	20	12.1	1st	12	11.4	1st	9	14.5	1st	41	12.3	1st
Availability of potential flowering plant	18	10.9	2nd	9	8.6	3rd	8	12.9	2nd	35	10.5	2nd
Water availability	17	10.3	3rd	8	7.6	4th	6	9.8	4th	31	9.3	3rd
Indigenous beekeepers knowledge	14	8.5	6th	6	5.7	6th	4	6.5	6th	24	7.2	8th
Market demand for beehive products	15	9.1	5th	7	6.7	5th	7	11.3	3rd	29	8.7	4th
Establishment of livestock and fish resources department office	7	4.2	11th	6	5.7	6th	2	3.2	8th	15	4.5	10th
Presence of GOs and NGOs who are involved in beekeeping activities	13	7.9	7th	7	6.7	5th	5	8.1	5th	25	7.5	7th
High soil and water conservation practice and area enclosure	16	9.7	4th	8	7.6	4th	4	6.5	6th	28	8.4	5th
Beekeeping experience of the farmer	10	6.1	9th	6	5.7	6th	3	4.8	7th	19	5.7	9th
Availability of tourists in the area	6	3.6	12th	4	3.8	8th	2	3.2	8th	12	3.6	12th
Road construction	5	3.0	13th	8	7.6	4th	2	3.2	8th	15	4.5	10th
Availability of micro-finance institution for small scale credit facility like (ACSI)	9	5.5	10th	5	4.8	7th	3	4.8	7th	17	5.1	8th
Availability of queen rearing center in Sekota Dry Land Agricultural Research Center	3	1.8	14th	9	8.6	3rd	2	3.2	8th	14	4.2	11th
Socio economic value	12	7.3	8th	10	9.5	2nd	5	8.1	5th	27	8.1	6th

area for easy access of beehive products and to get beehive inputs easily. Another opportunity of the study area is the presence of research area in nearby Sekota Dry Land Agricultural Research Centre (SDLARC) who is involving in queen rearing practice and studying the major constraint of the beekeepers in the locality. The institute also provides training to beekeeper farmers, bee experts and technicians and also supplied different beekeeping inputs or equipments or materials to improve beekeeping practice and honey production. Furthermore, it has the role of disseminating new techniques to beekeeper farmers like splitting and queen rearing techniques as indicated in Table 14.

In line with this, Atsbaha et al. (2015) reported that the major opportunities for bee keeping are: existence and abundance of honeybee, availability of potential flowering plants, availability of water sources for bees, beekeepers experience and practices, land rehabilitation and credit availability. In general, based on the beekeeper response, key informant and participants in the focus group discussion confirmed that the study area has ample opportunities and potentials for beekeeping practice and honey production, however, the expected output from this subsector has not been exploited yet due to various challenges and problems stated in this study (Table 11).

CONCLUSIONS

It can be concluded that beekeeping in Abergell, Sekota and Gazgibala districts contribute a great deal to the household welfare in terms of income generation. Beekeeping activities in the study area is the third income generation tasks next to crop and livestock production. The area is suitable for honeybee production because of availability of honeybee colony, different bee forages in different season and better experience in rearing beekeeping. Various constraints have been bottleneck to exploit the untapped potential of bee keeping in the study area. The major ones are lack of rain fall due to consecutive drought in the area, lack of bee forage associated with deforestation, prevalence of pest and predators, shortage of water, poor farmers awareness and indiscriminate agrochemical utilizations, and shortage of beekeeping equipment were reported by the respondent households as the most important constraints of honey production in the districts. Regardless of availability of constraints, beekeeping was found to have a number of opportunities which demands for the sub-sector to be encouraged in the study area. Based on the results of this study, the following recommendations are forwarded for improving beekeeping activities in the study areas.

RECOMMENDATIONS

(1) Designing effective honeybee pests and predators controlling methods.
(2) Introduction of full package improved beekeeping technologies with adequate practical skill training on all bee keeping trends and queen rearing practices on which farmers get and enhance a bunch of queens and new colonies
(3) The awareness of the farmers should be improved by different training activities and it is essential to establish strong linkage between the farmers, the development agents and the research institutions.
(4) Providing sufficient beekeeping equipments and credit also increases the farmers involvement in beekeeping practices.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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The bio-efficacy of *Calpurnia aurea* against *Sitophilus zeamais* (Motschulsky) (Coleoptera; Curculionidae) of stored maize under laboratory condition in Ethiopia

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N-hexane (non-polar), chloroform (partial polar), distilled water, methanol, acetone and ethanol (polar) extracts (10 g/100, 20 g/100 and 20 g/100 ml extraction levels) and leaf powder of *Calpurnia aurea* were tested as protectant against maize weevil, *Sitophilus zeamais* on filter paper and in maize grains under laboratory condition. The extracts and powder were applied at rate of 2 and 3 ml on filter paper and at a rate of 5, 10 and 15% (w/w) on admixture bioassay. Parental adult's mortality, F1 progeny emergence, percent protection, percent grain damage and weight loss were measured as efficacy determining parameters. Polar solvent extracts of the *C. aurea* applied at all rates on filter paper from all levels of extraction induced significant ($p < 0.05$) toxicity effect compared to partial and non-polar solvent extracts, as well as the negative controls. Besides, hundred percent adult weevil's mortality was induced by all polar solvent extracts of *C. aurea* applied at rate of 3 ml per filter paper from 30 g/100 ml level of extraction 24 h after treatment application. Furthermore, the powder of *C. aurea* applied at all rates was also induced significantly good degree of protection of maize grains against F1 progeny emergence (≥ 78%), percent grain damage (≤ 4.00) and weight loss (≤0.50) by maize weevils in about 2 month's storage period. Therefore, leaf powder and the solvent extracts of *C. aurea* were potent and could be used for managing maize weevils on stored maize under farmer's storage conditions in Ethiopia.

Key words: botanicals, *Calpurnia aurea*, *Sitophilus zeamais*, solvent extracts, leaf powder.

INTRODUCTION

Maize is the major staple food in Africa contributing significantly to the agricultural sector (Tefera et al., 2011). However, during storage, it is heavily attacked by various insect pests, of which the maize weevil, *Sitophilus zeamais* is most economically important. Accordingly, these insect pests have been reported to be responsible for loss ranging from 30 to 90% in Ethiopia (Getu, 1993) and losses ranging from 40 to 100% in Malawi (Denning et al., 2009).

Thus, they have been recognized as an increasingly

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serious problem in Africa (Markham et al., 1994; Abebe et al., 2009; Tefera et al., 2011), indicating great need for safe grains storage and control interventions. However, control of these insect pests has been heavily relied on the use of synthetic insecticides. This has led to development of resistance strains, environmental and health concerns (Ofuya and Longe, 2009). As a result, the search for the development of safe, affordable and eco-sound alternatives, such as botanicals, has been inspired.

Calpurnia aurea (Ait.) Benth plant may have protective role of stored maize against weevils. It is a small, multi-stemmed tree, 3 to 4 m tall plant. It is widely distributed in Ethiopia. It is widely grown in high land areas (Birhanu and Asale, 2015) and is easily cultivated (Germishuizen and Meyer, 2003). The plant has been commonly used in traditional medicine to treat different medical disorders and parasitic infections, in animals and in humans in Africa including Ethiopia (Watt and Breyer-Brandwyk, 1962). Its leaves and powdered roots are used to destroy lice and to relieve itches and they contain terpenoids, saponins, tannins, flavonoids, steroids, glycosides and alkaloids (Nega et al., 2016).

The objective of the present study was to evaluate the toxicity potency of leaf powder and solvent extracts of the plant against the most economically important storage insect pest of maize and maize weevil (*S. zeamais*) under laboratory conditions.

MATERIALS AND METHODS

The study period

The study was conducted in between 1, October to 30, June of 2016/2017 in the insect science laboratory of zoological science department of Addis Ababa University of Ethiopia.

The test insect's culture

S. zeamais adults were collected from maize stored in various farmers' traditional storage facilities of major maize producing localities Shashogo and Sankura Districts of Southern Ethiopia, and brought to the laboratory insect science stream of zoological science department of Addis Ababa University of Ethiopia. These test insects were cultured at 27±3°C and 55 to 70% RH (Jembere et al., 1995; Zewde and Jembere, 2010).

Shone variety of maize grains were obtained from farmer's storages of the survey site. It was the most commonly grown hybrid in the region and considered to be susceptible to insect infestation (from survey finding). The grains were kept at -20±2°C for 2 weeks to kill any infesting insects, cleared of broken kernels and debris and then graded manually according to size, and similar sized grains were selected for the experiment (Gemechu et al., 2013).

Following the methods by Zewde and Jembere (2010), fifteen pairs of the adult of the test insects were placed in 12.1 L glass jars containing 250 g seeds. The jars were then covered with nylon mesh and held in a place with rubber bands to allow ventilation and to prevent the escape of the experimental insects. The parent of the test insects were sieved out after an oviposition time of 14 days. Then, the jars were kept under the aforementioned laboratory condition until F1 progeny emerged. The F1 progeny, which emerged after 30 days, were sieved out and used for the experiment.

Solvent extract of plant materials

Ground plant material (powder) from the leaves of the test plant was soaked in n-hexane (non-polar), chloroform (partial polar), distilled water, methanol, acetone and ethanol (polar) at the rate of 10 g /100, 20 g /100 and 30 g /100 ml of each solvent (Jembere, 2002). The solution was allowed to stand for 24 h for extraction. After 24 h, the mixtures were filtered with cheese cloth. Then, the filtrates were ready to be used for the different treatments following similar procedures by Zewde and Jembere (2010).

Filter paper bioassay

Following similar procedures of Zewde and Jembere (2010), different levels of each solvent extracts were applied to a filter paper of 9 mm diameter at the rate of 2 and 3 ml per filter paper, and placed in a Petri dish of 10 cm diameter. Variable exposure times were considered, which were based on the nature of the solvent. In case of acetone and methanol, the exposure time was 30 min, while it was 60 min for ethanol (Jembere, 2002). Then, 1 ml of distilled water was added to the entire surface of each treated filter papers, as a carrier of the extracts. Other filter papers were treated with two levels of different solvents as control. After treatment, 5 pairs of 3 to 7 days old unsexed experimental insects were introduced into the treated and control filter papers in the petri dishes. Mortality of the adult insects was counted after 24, 48, 72 and 96 h. When no leg or antennal movements were observed, insects were considered as dead as suggested by Gebre selase and Getu (2009). All treatments of filter paper were arranged in Completely Randomized Design (CRD) in three replications.

Admixture bioassay with botanicals powder

Following the methods by Gebre selase and Getu (2009), 100 g of disinfected maize grains of shone varieties (that were disinfested using the same procedure as indicated in insect culture section) were introduced into 1 L glass jars that were treated differently with the powdered peels of the test plant (that is, 5, 10 and 15 g of the powder) for treatment of powder. Malathion (5%) dust was used as the positive control at a dosage of 0.05 g / 100 g maize grain and untreated grains were served as the negative control. The jar contents were shaken thoroughly for 5 mins to ensure uniform distribution of the treatments with grain surface. After treatment, 20, three to seven-day old experimental insects of unsexed were introduced to the treated and untreated seeds in the glass jars. Then, the jars were covered with nylon mesh and held in place with rubber bands. The treated grains and controls were kept under same experimental condition indicated in insect culture section. All treatments of powder were arranged in CRD in three replications. Mortality observation in the dried powder experiment (the number of dead insects in each jar were sieved and counted) was conducted at 1, 2, 3, 4, 7 and 14 days after treatment application. All live and dead insects were sieved and discarded after 13 days of introduction.

F1 progeny assessment bioassay

The treated grains and controls were also kept until emergence of F1 progeny under same experimental condition indicated in insect capture section after mortality observation. Then the numbers of F1 progeny produced by the experimental insects were counted. Counting was stopped after 56 days from the day of introduction to avoid overlapping of generation (Zewde and Jembere, 2010).

Damage and weight loss assessment

Two days after the last F1 count of 56 days, samples of 100 g were taken randomly from each jar and the number of damaged (grains with characteristic hole) and undamaged grains were counted and weighed. Grain damages were conveyed as a percentage of the entire number of grains in each of the aforementioned three replicates. Percentage weight losses were calculated by count and weight method following the methods by FAO (1985), Boxall (1986), Haile et al. (2003) and Haile (2006) as follows:

$$\%\ \text{Loss in weight} = \frac{\text{UNd - DNu}}{\text{U (Nd + Nu)}} \times 100$$

Where:

U = weight of undamaged grain, D = weight of damaged grain, Nd = number of damaged grain and Nu = number of undamaged grain.

As adopted by Gebre selase and Getu (2009), percent protection or inhibition in F1 progeny emergence (% IR) was also calculated using the following formula:

% IR = (Cn-Tn) x100⁄ Cn, where Cn is the number of newly emerged insects in the untreated (control) jar and Tn is the number of insects in the treated jar.

Data analysis

The data's collected for this study were managed by the Microsoft Excel package 2013 and analyzed using the Statistical Program for Social Sciences (SPSS) version 16. To observe the effects of botanicals treatments against weevil's adults' mortality and F1 progeny emergence, as well as grain damage and weight loss of maize grains at a particular time, appropriate statistical methods, Univariate analysis (for the former one) and one-way analysis of variance (ANOVA) (for the rest of parameters measured) were used. Standard errors (±se) were given following means in tables and in the form of error bars in figures. Correlation between the treatments and the efficacy measuring parameters were determined using Pearson's correlation of SPSS program of version 16.

RESULTS

Filter paper bioassay

Percentage adult weevil's mortality was increased ($p < 0.05$) significantly with increased dosage (concentration), extraction level, polarity and exposure time after treatment for the tested botanical in general. Polar solvent extracts (distilled water, methanol, ethanol and acetone extracts) of the *Calpurnia aurea* applied at all rates (2 and 3 ml) from all of the three levels of extraction (10 g/100, 20 g/100 and 20 g/100 ml) induced significant ($p < 0.05$) toxicity effect compared to non-polar and partial solvent extracts, as well as the negative controls (solvents alone) (Figure 1). Significantly, ($p < 0.05$) higher mean percentage mortality of *S. zeamais* (≥ 60 and ≥ 80%) was occurred in all polar solvent extracts (distilled water, methanol, ethanol and acetone extracts) of the tested plant applied at a rate of 2 and 3 ml per filter paper from the higher level of extraction (20 and 30 g/100 ml), respectively 24 h after treatment. Besides, hundred percent adult weevil's mortality was induced by all polar solvent extracts of *C. aurea* applied at rate of 3 ml per filter paper from 30 g/100 ml level of extraction 24 h after treatment application (Figure 1).

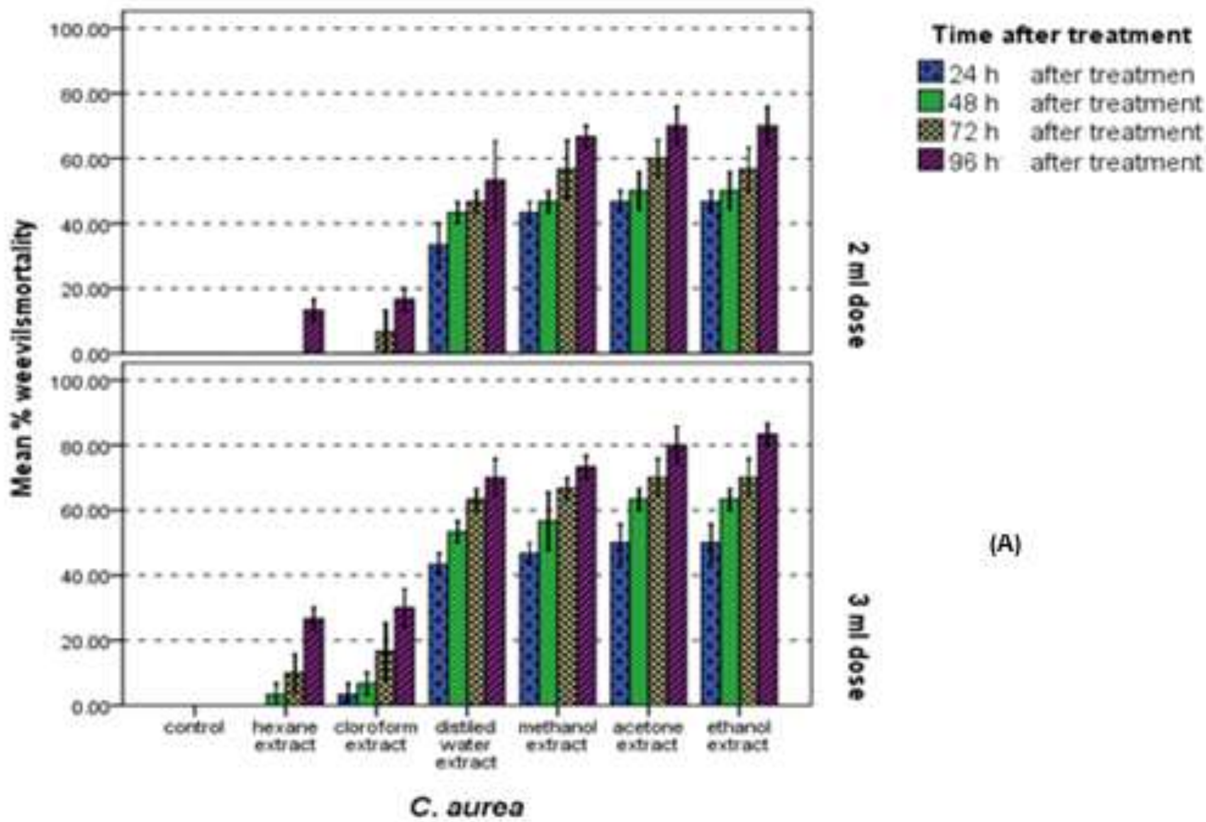
Admixture bioassay

The percentage adult weevil's mortality was increased significantly ($p < 0.05$) with increased dosage (concentration) and exposure time after treatment for the tested botanical in general in all bioassays tested. The tested botanical had significant ($p < 0.05$) effect on percent mortality of adult weevils in comparison to the untreated grain (negative control). However, significant percentages weevil's mortality were not induced at 5 and 10% rates of the tested botanical prior to four days of post treatment exposure (Figure 2).

Significantly, ($p < 0.05$) high weevil's mortality (≥50%) was caused by all treatments of the tested botanical applied at all dosages, following four days treatments post exposure, as compared to 1 to 3 days after treatment and untreated grains. Besides, the weevil's mortalities were significantly ($p < 0.05$) higher (≥ 83%) in all treatments of the tested botanical applied at 5% dose and it became 100% in all treatments of the tested botanical applied at rates of 10 and 15%, 7 days after treatment application. Furthermore, the magnitude of mortality became 100% in all treatments of applied at all rates of the test botanical, following 14 days of treatment application similar to that of the positive control or Malathion 5% dust applied at recommended dose (Figure 2).

The number of F1 adult progeny produced, percentage grain damage and weight loss caused by *S. zeamais* in all treatments of botanical leaf powder were significantly ($p < 0.05$) lower compared to negative control (untreated cheek). Almost all leaf powders treatments of the tested botanical applied at higher dosage (10 and 15%) induced more than 78% protection in F1 progeny production by *S. zeamais* respectively as compared to negative control. Similarly, almost all leaf treatments of the tested botanical caused significantly ($p < 0.05$) higher reduction in grain damage (≤4.00) and weight loss (≤0.50) of maize grain as compared to the negative control.

Besides, 100% F1 progeny production inhibition, as well as no grain damage and weight loss of maize were observed in powder treatments of the tested botanical applied at a rate of 15% likewise that of the positive control (Malathion 5% dust). However, significantly higher ($p < 0.05$) F1 emergence of *S. zeamai*s, grain damage


Time after treatment
24 h after treatmen
48 h after treatment
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96 h after treatment
Mean % weevilsmortality
100.00
80.00
60.00
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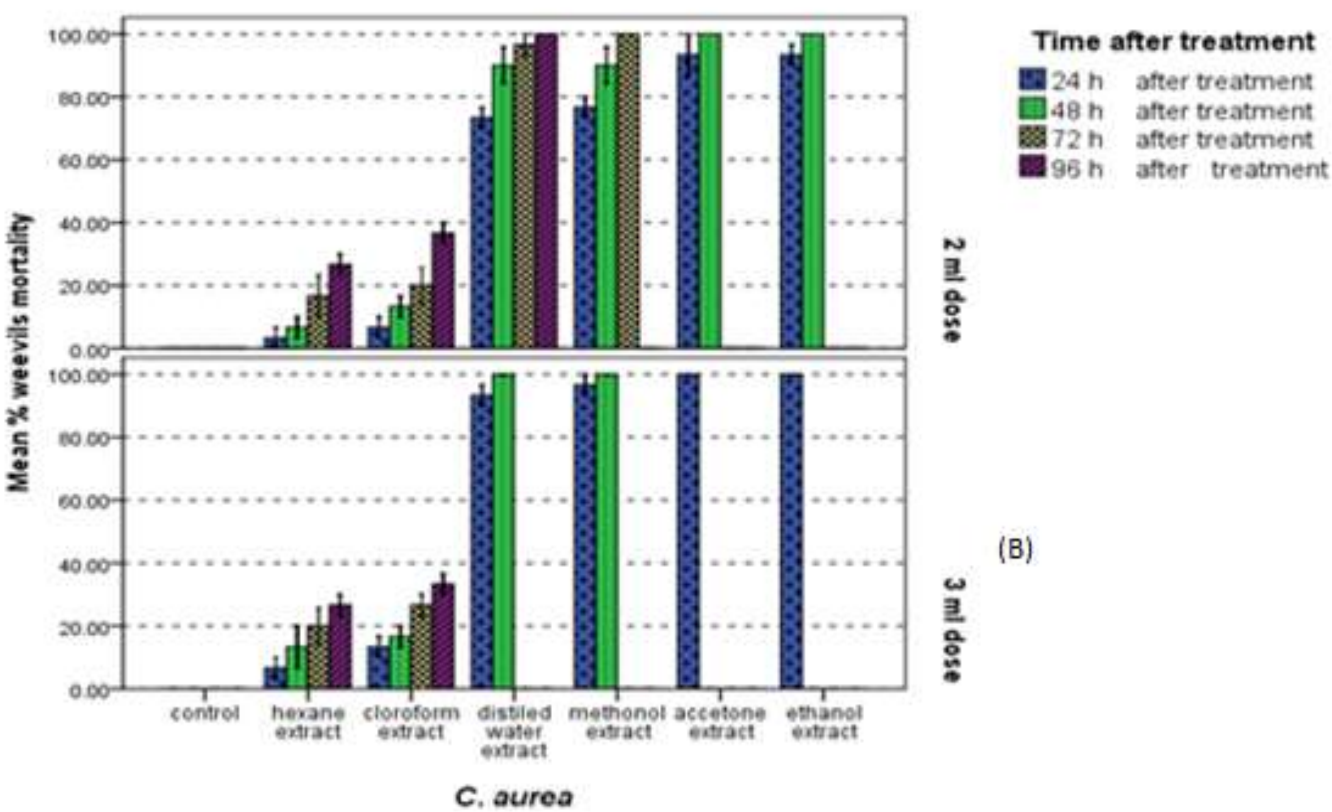
20.00
0.00
2 ml dose
3 ml dose
control
hexane extract
cloroform extract
distiled water extract
methanol extract
acetone extract
ethanol extract
C. aurea

(A)


Time after treatment
24 h after treatment
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Mean % weevils mortality
100.00
80.00
60.00
40.00
20.00
0.00
2 ml dose
3 ml dose
control
hexane extract
cloroform extract
distiled water extract
methonol extract
accetone extract
ethanol extract
C. aurea

(B)

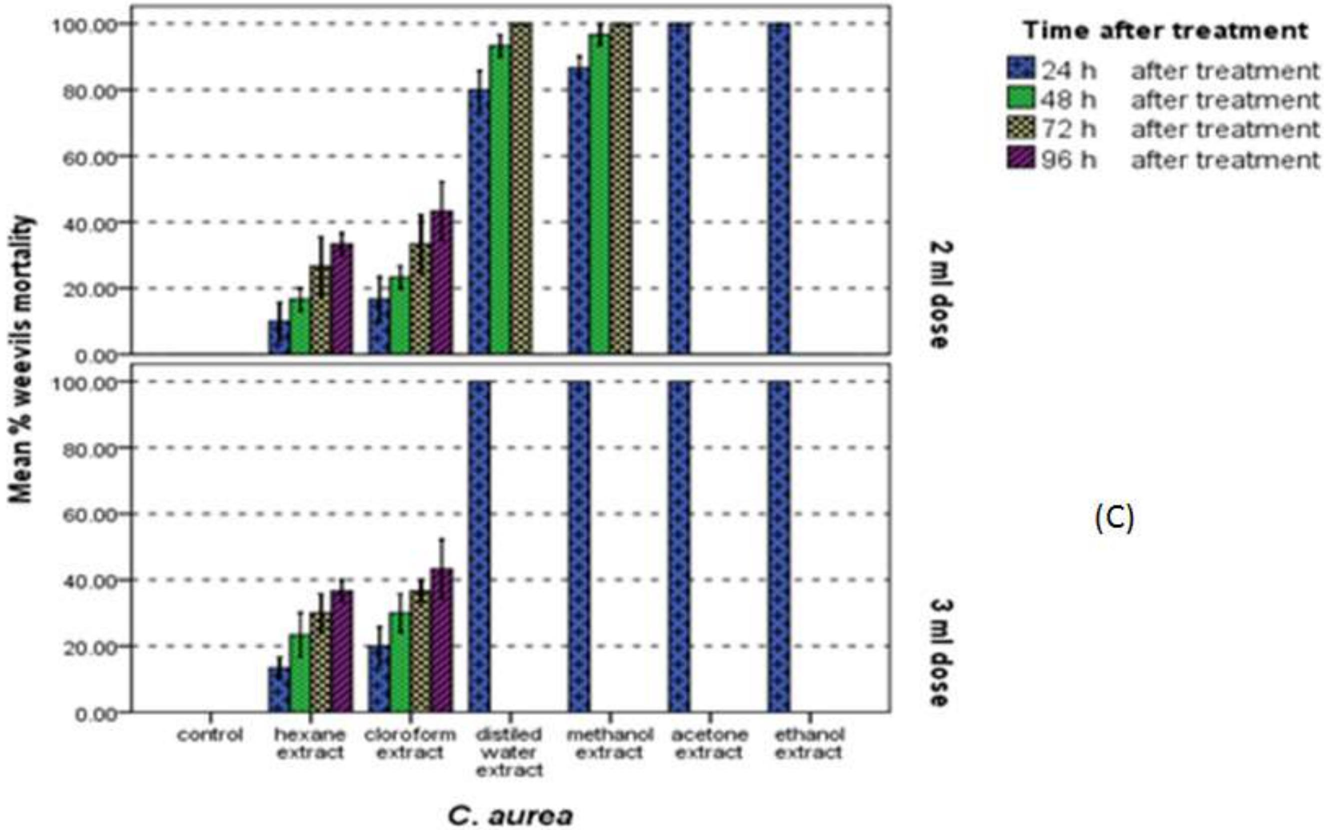

Figure 1. Mean % mortality (mean ± SE) of *S. zeamias* due to solvent extracts of *C. aurea* extracted at the rate of: 10 g / 100, 20 g / 100 and 30 g /100 ml and applied at the dose of 2 and 3 ml after different post treatment exposure.
Source: The different colors and markings at different days after treatment indicate means that are significantly different at p> 0.05.

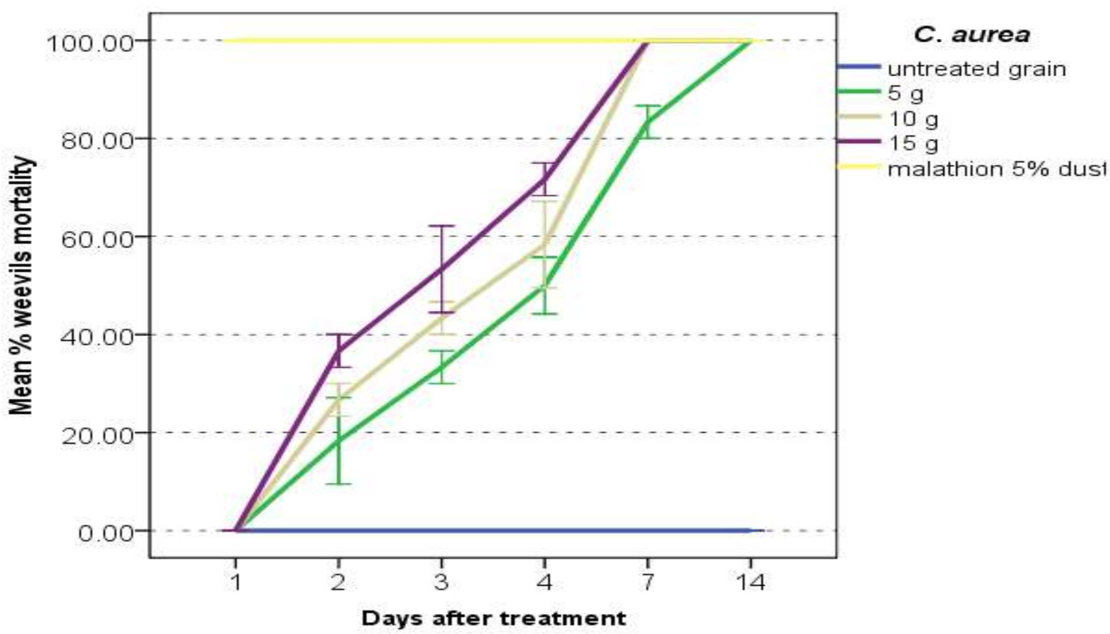

Figure 2. Mean % mortality (mean ± SE) of maize weevil adult exposed in grains treated with *C. aurea*.

Table 1. Mean number of f1 progeny produced, percent protection, grain damage and weight loss caused by *S. zeamais* on maize grains treated with *Calpurnia aurea* leaf powder.

Treatments	Dosage (g/100 g)	Mean number of F1 progeny	Percentage protection	Mean % grain damage	Mean % weight loss
Dosage	5	6.67±4.41^{c}	78.94	4.00±0.58^{b}	0.50±0.01^{b}
-	10	3.33±1.67^{b}	89.49	1.00±1.00^{ab}	0.22±0.01^{ab}
-	15	0.00±0.00^{a}	100	0.00±0.00^{a}	0.00±0.00^{a}
Malathion 5%	0.05	0.00±0.00^{a}	100	0.00±0.00^{a}	0.00±0.00^{a}
Control (untreated)	0	31.67±1.67^{d}	0.00	11.67c	5.30±0.17^{c}

Means followed by the same letter in a row are not statistically significantly different at p< 0.05.

Table 2. Correlation among efficacy determining parameters of CA leaf powder.

Efficacy determining parameters	Rate	F1 CA	% GDCA	% WLCA
Rate	1	-	-	-
F1CA	-0.943**	1	-	-
% GD CA	-0.920**	0.972**	1	-
% WL CA	-0.866**	0.920**	0.964**	1

Correlation coefficients with two asterisks (**) represent highly significant association at p values <0.01 (2-tailed), with hyphen (-) represent no association and those without asterisk are non-significant.
CA = Calpurnia aurea, GD = grain damage and WL= weight loss

and weight loss of maize grains occurred in powder treatments applied at lower dose (5%) when compared to those subjected to higher dosages (10 and 15%) (Table 1).

The correlations among the treatments of powder of the tested plant leaves applied at different dosage and the efficacy parameters measured were found to be highly significant. The correlations between the various treatments of powder of the tested plant leaves applied at different rates and the various parameters measured (the number of F1 progeny emerged, percentage grain damage and weight loss) were negative. However, the correlations between F1 progeny produced, and percent grain damage and weight loss of all treatments of the tested botanical powder were strongly positive. Besides, the correlations were strongly positive between the percentage grain damage and weight loss of all of the treatments of the tested botanical powder applied at different rates (Table 2).

DISCUSSION

The current study revealed that the percentage adult weevil's mortality was increased (p≤0.001) significantly with increased dosage (concentration) and exposure time after treatment for the tested botanical in general in bioassays tested. This result is in line with findings of pervious researchers (Gebre selase and Getu, 2009; Zewde and Jembere, 2010; Gebre-Egziabiher, 2016) in which mortality effect of botanicals were indicated to be dose and exposure time dependent.

The present study also revealed that polar solvent extracts (distilled water, ethanol and acetone extracts) of the tested botanical leaves at tested rates (2 and 3 ml in filter paper) from all extraction level induced significant toxic effect against *S. zeamais* as compared with negative control. This suggests the presence of more polar solvent soluble phytochemicals in leaves of *C. aurea* which are responsible for higher weevil's mortality. It also suggests the active phytochemicals of these botanicals were highly soluble in all of polar solvents (water, ethanol and acetone) and as most of them probably might be polar.

Similarly, Amante (2016) also suggested that the active ingredients in the leaf extract of the plant reside in the polar fractions indicating that the active principles are polar in nature after he studied castor bean plant against ectoparasites of animals. Jembere et al. (2005) also indicated that high *Z. subfasciatus* mortality was caused by *M. ferruginea* water extract that probably might be due to the presence of highly water-soluble chemicals in the seeds of *M. ferruginea*.

Getu (2014) also indicated that the polar solvent extracts (acetone and water) of *M. ferruginea* seeds caused significantly high toxicity to *Z. subfasciatus* 48 h after treatment. Furthermore, Blum and Bekele (2002) also reported that *C. aurea* has been used as a natural pesticide to improve grain storage. It was also indicated that *C. aurea* possess potent activities (louscidal and acaricidal effects) against ectoparasites of animals (Amante, 2016).

In the current study, all leaf powder treatments of the tested botanical also caused significant mortality of adult *S. zeamais* than negative control at all dates. Besides, all leaf powder treatments of the tested botanical induced higher mortality (100%) following 7 and 14 days of treatment application. These higher efficacies of leaf powder than negative control may be attributed to either the toxic effects of phytochemicals in the tested plant or starvation and interference with respiration due to suffocation of maize weevils. These results thus, suggest the potency of the leaf powder in protecting maize grains against weevils for the tested plants. Toxicity caused by crude extract of the tested botanical in the current study was also in accordance to the result of pervious researchers (Jembere et al., 2005; Zewde and Jembere, 2010; Gebre selase and Getu, 2009; Getu, 2014; Bulto et al., 2017).

Conclusion

The leaf powder and the polar solvent extracts of *C. aurea* were potent in protecting maize against maize weevils attack at all rates (at 2 and 3 ml in filter paper and 5, 10 and 15% for powder admixture bioassays). This in turn confirmed the presence of possibility to exploit the potential of *C. aurea* in the management of *S. zeamais* under subsistence farmer's storage condition. Thus, the powder extracts of *C. aurea* at 5% and above could be used for managing maize weevils on stored maize under subsistence farmer's storage conditions in Ethiopia and elsewhere with similar pest problems. However, their effect on human being, natural enemies and cost effectiveness in farmer's storage conditions need further study before wide implementation of outcomes this study.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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