Ethiop. J. Agric. Sci. 32(3) 17-36 (2022)

Pesticide Use Practices and Effects on Crop Yield, Human Health and the Environment in Selected Areas of Ethiopia

Dagne Mojo[1] and Lemma Zemedu[1]

Agricultural Economics Directorate, Debre Zeit Agricultural Research Center, Ethiopian Institute of Agricultural Research, P. O. Box 32, Bishoftu, Ethiopia

Abstract

Pesticides are crucial part of agriculture and human health irrespective of their potential risks. The aim of this study is to assess the practices of pesticide uses, benefits, and effects on human health and the environment using survey data collected from 775 farm household in selected areas of Ethiopia. The data are analyzed using descriptive statistics, frequency tables, and OLS regressions. The results show that about 99% of the households surveyed use at least one type of chemical pesticides, while 89%, 93%, 84%, and 15% use specific pesticides, respectively, for the control of weeds, fungi, insects, and rodents in the production of different crops. A substantial number of farmers also use traditional practices and new crop varieties as pest control methods. Conversely, 64% of the respondents perceived some kind of negative effects (poisoning or contamination) to humans, animals, or the environment by the chemical pesticides they have used on their farms. Pesticides are sprayed mostly by male household heads (65%) and sons (21%), who do not take a necessary precaution to reduce chemical hazards despite the partly available training (for 46% households) and extension services (63%). About 44% of the households dispose of expired pesticides on the soil, and 64% either spray on the soil or bury the leftover chemicals. Nevertheless, about 74% claimed that they know how to handle the pesticides; and nearly 90% of the households store the pesticides in places where children cannot access them. The OLS estimation results indicated that households who applied herbicides two times on wheat fields have obtained significantly higher yields (1.6 t/ha) than those who have not used herbicides for wheat production. In addition, those who applied fungicides once, twice, and three times have obtained about 1.4, 1.0, and 1.2 (t/ha) higher wheat yields than those who didn't use fungicides. Yet, herbicide application frequencies on teff farms have no statistically significant effect on teff yields. Most of the surveyed households have apparently benefited and satisfied with pesticide uses. However, it is imperative to focus on safety measures and management options to reduce the perceived pesticide risks. Establishing consulting service providers and the use of trained workers for spraying could reduce the negative effects of pesticides on human and animal health, and the environment. Furthermore, the traditional (non-chemical) pest control methods in practice among farmers should also be encouraged and promoted. Nevertheless, we suggest further quantification of health and environmental risks.

Keywords: Chemical pesticides, Environment, Ethiopia, Hazard, Human health, teff, wheat

Introduction

Pesticides, such as herbicides, insecticides and fungicides are a crucial part of agriculture and human health worldwide. They support the production of the growing food supply destined to feed the world's increasing population through improving productivity, reducing crop losses, and improving human health by controlling vectors that spread deadly diseases such as malaria (Cooper and Dobson, 2007; Aktar, Sengupta and Chowdhury, 2009; Fikadu, 2020). Yet, it has also been long recognized that the unsafe management and use of pesticides have had risks and negative impacts on humans, beneficial insects, non-target vegetation, fish, birds, wildlife, etc. (Begna, 2015; Negatu *et al.*, 2016; Mengistie, Mol and Oosterveer, 2017; Fikadu, 2020). The use of pesticides has, generally, brought on one hand tremendous benefit to humankind all over the world, and on the other, posed serious health and environmental risks.

Pesticides were first introduced into Ethiopian agriculture in the 1960s and have been gradually popularized since then (Amera Sahilu, 2016). In recent years, as farmers are getting aware of the benefits of pesticides, their demand in the agricultural sector has tremendously increased and has been accompanied by the increased number of pesticide importers and distributors. The benefit of pesticides is often estimated in terms of reducing significant yield losses due to pests. In Ethiopia and elsewhere in Africa, pests and disease can generally result in on average 30-40% crop yield losses (Abate, 1996). The author indicated that insect pests alone can result in 0-100% yield loss (varies with crop types) in Ethiopia. For instance, if not controlled through the uses of pesticides or other alternatives, insects can cause on average 32-60% losses in cereals; 19-63% in pulses; 24-49% vegetables; 2-9% citrus; and 36-60% cotton. Consequently, the majority of Ethiopian farmers currently use pesticides to control insect pests. Similarly, about 98% of farmers in the cereals growing area of the Jimma zone use herbicides to control weeds (Ocho *et al.*, 2016). Uncontrolled weeds can result, for example, 10-50% yield losses in wheat (Nakka *et al.*, 2019).

Along with the increased use of pesticides and unsafe management of the same, there is an increasing concern that the risks and the negative impacts of these chemicals on human and animal health as well as the environment have been also increasing in Ethiopia. For instance, a study conducted in the Jimma zone of Oromia indicated that less than 40% of farmers who used pesticides understand the signs on pesticide containers and 80% use normal clothes when spraying pesticides (Ocho *et al.*, 2016). Eventually, these farmers are under high risks since small and continuous exposures to and poisoning by agrochemicals are well documented as causes of breast cancer, male sterility, and other health-related problems (Pingali, 2001; Fianko *et al.*, 2011). Not only the farmers but also

consumers in urban areas are at a high risk of poisoning by pesticides due to the high possibility of pesticide residue accumulation in the edible parts of agricultural products. A study conducted in Ghana, for instance, indicated effects of pesticides in milk, vegetables, fruits, meat, fish meals and other food at different intervals (Fianko *et al.*, 2011).

Pesticides have also unwanted side effects on the environment through the contamination of soil, surface, and groundwater (Manda and Mohamed-Katerere, 2006; Aktar, Sengupta and Chowdhury, 2009). Studies indicate that less than 0.1% of applied pesticides reach the target pest, while the other 99.9% are pollutants to the environment (Sisay, 2009). On top of this, a large amount of obsolete pesticides have accumulated over the last 30-40 years in the country and are becoming a source of human health and environmental risks. Furthermore, although there is legislation governing pesticide registration and guidelines on import and screening, the appropriate use and management of pesticides has not been enforced effectively, and the policies and regulations are also outdated that in turn, increase the risks of pesticide use in Ethiopia. Pesticides unregistered in EU, such as Endosulfan and its related isomers, included under the Persistent Organic Pollutants (POPs) list in the Stockholm convention, are in use and formulated at the Adami Tulu pesticide plant (Amera Sahilu, 2016).

Regardless of the increasing uses and demands of agrochemicals in general and pesticides in particular in Ethiopia, there is inadequate information about the use practices, benefits and risks of those chemicals in the country. Therefore, this study is initiated to understand how pesticides are used, the perceived benefits, and the potential effects they have on the environment, human and animal health in selected areas of the country. This can help to suggest actions to be taken to maximize the benefits and to reduce the risks and negative impacts of agrochemicals in the country. Therefore, the overall objective of the article is to assess and generate information about the current state of pesticide use knowledge, benefits, effects in Ethiopia using household survey data collected through face-to-face interview. Specifically, we assess: (1) farmers' knowledge of pesticide uses and benefits, (2) perceived environmental, human and animal health effects, 3) and estimate the effects of pesticide application frequencies on crop yields.

Methods

Sampling and data collection techniques

A household survey was conducted in 2018 to collect qualitative and quantitative data about household demography, socioeconomic characteristics, pesticide uses,

and perceived health and environmental effects. Multistage and purposive sampling techniques were used for the selection of the study areas and sample households. In the first stage, the study areas (administrative zones, and districts) were purposively selected aiming to address major cereal crops growing areas. Accordingly, seven districts from five zones, namely Hetosa and Gedeb Assasa (in short Assasa) from Arsi zone, Sinana from Bale, Minjar-Shenkora (in short Minjar) from North Shewa, and Adea, Bora and Dugda districts from East Shewa zones were selected. In the second stage, representative 3-5 cereal crops growing kebeles per district were randomly selected. In the third stage, sample farm households were randomly selected from each of the kebeles proportional to the number of cereal growing farmers. A total of 775 sample households were then interviewed face to face with trained enumerators (**Table 1**). The household survey data were collected using computer-assisted personal interviewing (CAPIs) and paper-based questionnaires, and later merged into a single database.

Table 1. Sample size by administrative zones and districts

Zone	District	Sample size by district	Total sample by zone
Arsi	Etosa	97	196
	Gedeb Assasa	99	
Bale	Sinana	107	107
North Shewa	Minjar Shenkora	100	100
East Shewa	Adea	89	372
	Bora	81	
	Dugda	202	
	Total		775

Methods of data analysis

The household survey data collected were coded, cleaned, and prepared for statistical analysis using STATA. The data were then summarized and described using means, frequencies, and graphs.

The econometric analyses were also conducted using the multiple linear regression models and the Ordinary Least Square (OLS) estimation methods to assess the effects of pesticide application frequencies (as one of the explanatory variable) on wheat and teff yields as dependent variables.

Results and Discussions

Demographic and socioeconomic characteristics of the sample households

The demographic characteristics of the sample households are shown in **Table 2.** The summary results indicate that the average age of the household heads is 41 and ranges between 18 and 80 years. While 94% of the surveyed households are male-headed, the average family members of the whole sample households are 6, of which 4 are within the active working ages (14 - 64 years). The number of

household members and active members of the sample ranges, respectively, from 1 to 27 and from 0 to 20. The average education level of the household heads is 4 years of schooling and ranges between 0 and 21. By grouping into categories, about 15% of the household heads are illiterate (cannot read and write), while 67, 14 and 3% have attained, respectively, elementary (1-8), secondary (9-12) and tertiary (12+) school educations (results are not displayed due to space limitation). The Chi^2 test, in this case, indicates a statistically significant variation in education level among districts.

The sample households, on average, own two oxen, the maximum owned being 16 while there are also households who have none (**Table 2**). In sum, the average livestock (oxen, cows, sheep, and goats) owned in the study areas is about 5.23 in Tropical Livestock Units (TLU). Similarly, the average land owned by the sample households is about 1.66 ha with a minimum of 0 (who rely on rented in or shared in land) and a maximum of 10.5, although there are variations among the districts. Livestock and landholding are among the important household assets that may affect households' decisions to use agricultural inputs, including pesticides.

The results also show that only 44% of the sample households in the study areas are members of agricultural cooperatives, although more numbers of households were expected to be members due to the intended effects of cooperatives on farmers' access to various agricultural inputs, including pesticides (**Table 2**). There is a statistically significant difference ($p < 0.000$) in number of cooperative members among the districts. While Minjar Shenkora has the largest proportion of cooperative members (89%), Bora has only 12% of the households who are cooperative members (results not displayed).

Wheat and teff are the major cereal crops grown, respectively, by 77% and 44% of the households in the study areas (**Table 2**). It can also be seen in the table that 70% and 63% of the producers, respectively, used improved varieties of wheat and teff. The average yield of wheat is 3.2 t/ha, while that of teff is about 1.0 t/ha. The sample households also apply about 122 kg/ha of NPS and 57 kg/ha of urea for wheat while they use 133 kg/ha of NPS and 62 kg/ha of urea for teff (**Table 2**). Some of the other crops grown in the study areas are: onion (produced by 36% of the respondents), maize (31%), barely (20%), faba bean (13%), cabbage (13%), chickpea (13%) and tomato (9%).

Table 2. Demography and socioeconomic characteristics of sample households

Variables	Obs	Mean (Prop.)	SD	Min	Max
Age of household head in years	773	40.86	12.21	18	80
Sex of household head (1= male; 0 = female)	773	0.94	0.23	0	1
Family size (number of household members)	771	6.29	3.40	1	27
Active household members (age between 14 and 64)	772	3.63	2.58	0	20
Marital status (1= married, 0= otherwise)	773	0.91	0.29	0	1
Education level of household head (years of schooling)	773	4.37	3.91	0	21
Total number of oxen owned	690	2.13	1.42	0	16
Total livestock in TLU (Tropical Livestock Unit)	773	5.23	4.39	0	40.72
Total land owned (ha)	771	1.66	1.39	0	10.5
Membership in a cooperative (1=Yes, 0=otherwise)	772	0.44	0.50	0	1
Households produce wheat (1= Yes, 0= otherwise)	773	0.77	0.42	0	1
Use improved wheat variety (1=Yes, 0= otherwise)	590	0.70	0.46	0	1
Wheat yield (t/ha)	588	3.18	1.57	0.2	8.0
Wheat area (ha)	596	1.22	1.04	.25	10
Wheat seed rate (kg/ha)	586	174.76	45.41	100	300
Wheat urea kg/ha	592	54.98	57.68	0	300
Wheat NPS kg/ha	589	116.44	84.63	0	400
Households produce teff (1= Yes, 0= otherwise)	773	0.44	0.50	0	1
Improved teff variety (1=Yes, 0= otherwise)	334	0.63	0.48	0	1
Tef yield (t/ha)	333	1.02	0.62	0	3.5
Tef area (ha)	336	0.81	0.60	0.06	3
Tef seed rate (kg/ha)	335	40.07	21.90	15	100
Tef urea kg/ha	340	51.34	57.43	0	400
Tef NPS kg/ha	340	109.77	108.66	0	500
N	773				

Pesticide use practices and benefits

The summary of pesticide use practices, as well as access to training and extension services, are shown in **Table 3.** About 99% of the households surveyed use at least one type of chemical pesticides, and 89%, 93%, 84%, and 15% use, respectively, for the control of weeds, fungi, insects, and rodents in the study areas some times during a crop production season. Other similar studies conducted in different parts of the county also showed a high proportion of households who use chemical pesticides. For example, about 82% of the households in Bule Hora district (Ligani, 2016), and 82% in different districts of the Amhara region (Begna, 2015), use chemical pesticides for crop production. Nevertheless, the proportion of households who use pesticides varies with the kind of crops produced and the types of pesticides needed. For example, unlike our findings where fungicides were used by the highest proportion of households (93%), herbicides were the most commonly used type (by 98% farmers) in some other areas (Begna, 2015). Although the amount varies for different herbicide types, farmers use about a liter of herbicides per ha for wheat and about half a liter per ha for teff productions. Similarly, farmers may also apply as many rounds as per their needs, or depending on the occurrences of the diseases. The wheat growers in our study apply

pesticides on average more than once while some other farmers apply up to five rounds on wheat fields **(Table 3)**. Another study also showed that 85% of the farmers interviewed had applied pesticides four times in a year on cereal crops such as wheat and teff (Ligani, 2016). Given the low level of education of farmers in Ethiopia, training and extension services on pesticide uses and management are believed to reduce pesticide risks and hazards. Yet, finding indicated that training and extension services on pesticide uses and management are not yet fully available for every farmer in the study areas. Only 46% of the surveyed households have received training on pesticide uses and management, though 63% of the respondents have access to extension services at least within their districts **(Table 3)**. In line with this, another study also showed that 69% of the respondents received extension services and are aware of proper use of pesticides (Begna, 2015). In other studies about 85% (Negatu *et al.*, 2017) and 81% (Agmas and Adugna, 2020) of individuals who spray chemical pesticides had not received any training on pesticides.

Table 3. Pesticide use practices

Variables	Obs	Prop/Mean	SD	Min	Max
Households use pesticides (1=Yes, 0=otherwise)	773	0.99	0.09	0	1
Use pesticides for weed control (1=Yes, 0= No)	767	0.89	0.32	0	1
Use pesticides for fungi control (1=Yes, 0= No)	767	0.93	0.25	0	1
Use pesticides for insect control (1=Yes, 0= No)	767	0.84	0.37	0	1
Use pesticides for rodent control (1=Yes, 0= No)	585	0.15	0.36	0	1
Received training on pesticides (1= Yes; 0 = otherwise)	773	0.46	0.50	0	1
Extension services on pesticides (1= Yes; 0 = otherwise)	773	0.63	0.48	0	1
Frequency of herbicide application for Wheat	463	1.34	0.60	1	5
Frequency of herbicide application for Tef	323	0.56	0.64	0	3
Amount of herbicide used for Wheat lt/ha	464	0.93	0.56	0	4
Amount of herbicide used for Tef per lt/ha	340	0.47	0.65	0	4
N	773				

Farmers also use traditional pest control methods as a supplementary option to reduce the crop damages by pests. Eighty-seven percent of the respondents have used hand weeding and repeated plowing for weed control while crop rotation has been also used by 67% of the households for weed control and by 39% for fungi control (**Figure 1**). Similarly, about 35% and 38% of the households reported that they use improved crop variety as a means to control insects and fungi infestations, respectively.

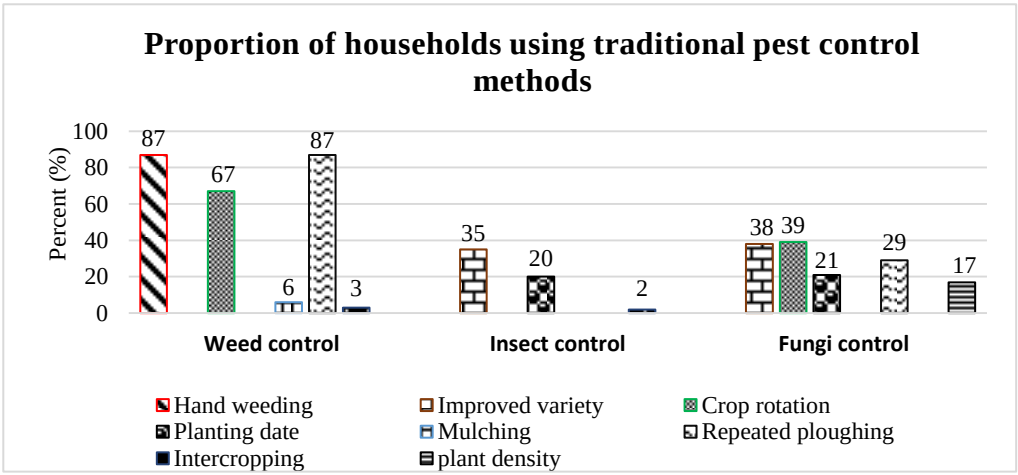

Figure 1. Proportion of household using traditional pests control methods

Most of the surveyed households seem benefited and satisfied with the effectiveness of the pesticides they used. Eighty-seven percent of the households who used herbicides and fungicides, and 83% who used insecticides reported that the problems of crop pests have been solved by the use of respective pesticides (**Table 4**). Similarly, more than 90% of the households reported that the use of herbicides and fungicides has increased crop production and productivity of their farms. In general, about 94% of farmers in another study perceived that pesticides are useful in crop production (Ligani, 2016). Because of the seeming effectiveness of chemical pesticides in pest control, a larger proportion of households reported increased use of pesticides over the last few years (**Table 4**). The increasing use of pesticides could also be partly because of farmers' acquired knowledge and skills about the benefits of pesticides through their own observation, training and extension services, and possible spillover effects in the study areas.

Table 4. Perceived benefits and trends of pesticide use

Variables	Herbicide	Fungicide	Insecticide
Pesticides solved your pest problem (%)			
Yes	87	87	83
*N**	732	730	696
Pesticides increased level of crop production (%)			
Yes	90	93	82
N	679	674	693
Pesticide use trends over the last three years (%)			
Increasing	74	85	77
Decreasing	6	3	9
The same	21	12	14
N	716	718	720
** N is a total number of households responded.*			

Effects of frequencies of pesticides application on yields of wheat and teff

The goal of pesticide use in crop production is to obtain better yields by reducing the damages that could have happened by pests. We indicated in the previous section that more than 99% of the households surveyed use at least a pesticide for crop production (**Table 3**). As a result, it has not been practicable to look into the effects of using or not using pesticides on crop yields. Rather we found it appropriate to evaluate whether the application frequencies of pesticides have effects on yields of selected crops. As wheat and teff are the major cereal crops grown in most of our study areas, we investigated the extent of the effect of pesticide application frequencies on wheat and teff yields.

The OLS estimation results (**Table 5**) show that some factors, such as the age of the household head, total land allocated for wheat production, the amount of NPS applied, extension services, and pesticide application frequencies are positively and significantly associated with wheat yields. For instance, applying herbicides twice has statistically significantly ($p<0.1$) associated with wheat yield. That is, households who have applied herbicides twice obtain about 1.6 (t/ha) higher wheat yield than those who have not used herbicides at all. Similarly, there is a highly significant ($p<0.001$) positive effect of fungicide application frequencies on wheat yields. Households who applied fungicides once, twice, and three times have obtained about 1.4, 1.0, and 1.2 (t/ha) higher yields than those who didn't use fungicides for wheat production (**Table 5**). However, a necessary precaution has to be taken when interpreting these results as pesticide application usually depends on the occurrence of pests, weather, and climatic conditions.

Table 5. Effect of frequencies of pesticides application and other factors on yields of wheat

Variables	Coef.	Std. Err
Age of the household head	1.15***	0.41
Age of the household head Squared	-0.01**	0.00
Education level of the head in years of schooling	0.22	0.22
Number of active household members aged between 15 and 64 years	-0.53*	0.30
Are you a member of any cooperative?	-0.93	1.60
Area of wheat ha	5.95***	0.98
Seed rate of wheat (kg/ha)	0.02	0.02
Amount of urea used for wheat (kg/ha)	0.01	0.02
Amount of NPS used for wheat (kg/ha)	0.02*	0.01
Total number oxen owned	-1.37*	0.77
Use crop rotation as traditional methods to control weeds (Y/N)	0.02	1.82
Use hand weeding as traditional methods	1.89	2.23
Agricultural extension services on pesticide use (Y/N)	3.88**	1.81
Received training about pesticides	1.84	1.52
Frequency of herbicides applied on wheat		
No application (reference group)		
Once	12.76	9.22
Twice	16.29*	9.37
Three times	11.54	9.79
Frequency of fungicides on wheat		
No application (reference group)		
Once	13.50***	3.98
Twice	9.92***	2.28
Three times	11.50***	2.45
Total expenditure on pesticide for wheat (in 1000 Birr)	-0.03	0.22
Amounts of herbicides used lt per ha	-0.34	1.29
Constant	-29.53**	13.83
R^2	0.40	
N	365	

* $p<0.1$; ** $p<0.05$; *** $p<0.01$

In the case of teff, the total area allocated for teff production has a significantly positive association with teff yield, which implies farmers who have allocated more land would put more management efforts and hence got better yields. However, herbicide application frequencies have not shown a statistically significant association with teff yields (**Table 6**). This could be because households who don't apply herbicides but use hand weeding as alternative ways of weed control, might have been as effective as those who applied herbicides. In fact, about 95% of the teff growers (including most of those who use herbicides) use hand weeding as a traditional method of weed control; about half of the surveyed households don't use all the three pesticide types, and almost all the households don't use fungicides and insecticides on teff plots (results not displayed). In line with our findings, an experiment conducted to evaluate the effect of different types and rates of herbicides on teff yield showed an insignificant difference between the yields of teff under untreated control and treatments (Davison, J., Creech, E., & Laca, 2010). The same study showed that applying mixed herbicides (as a treatment) at a boot growth stage of teff, has

resulted in significantly lower teff yield compared with that of other independent treatments (unmixed herbicides) and the control. Similarly, our results highlighted that the amount of urea applied has a negative association with teff yield, which seems unusual. However, another study also showed that increased application of N fertilizers on teff in some locations in Ethiopia has no positive response and even has decreasing response on yield (Ayalew and Kena, 2011). This could be related to the lodging problems of teff that are exacerbated by the addition of urea and in turn, have a negative effect on yields.

Table 6. Effect of frequencies of pesticides application and other factors on yields of teff

Variables	Coef.	Std. Err
Age of the household head	0.23	0.19
Age of the household head squared	-0.00	0.00
Education level of the household heads	0.12	0.10
Number of active household members aged between 15 and 64 years	-0.13	0.20
Districts		
Etosa		
Gedeb Assasa	4.41	4.50
Sinana		
Adea	1.84	3.69
Minjar Shenkora	1.70	3.58
Bora	-3.16	3.72
Dugda	-1.69	3.75
Are you a member of any cooperative?	0.57	0.94
Area of teff in ha	3.94***	0.74
Seed rate of teff in (kg/ha)	-0.03	0.02
Amount of urea used for teff (kg/ha)	-0.02***	0.01
Amount of NPS used for teff (kg/ha)	0.00	0.00
Total number oxen owned	-0.11	0.23
Use crop rotation as traditional methods to control weeds (Y/N)	-0.32	0.95
Hand weeding	-0.08	1.79
Agricultural extension services on pesticide use (Y/N)	-0.98	0.79
Households received training about any of the pesticides	-0.37	0.83
Frequency of herbicides applied on teff		
None		
Once	-0.49	1.27
Twice	0.17	1.86
Amounts of herbicides used (lt/ha)	-1.28	0.82
Constant	6.11	5.39
R^2	0.21	
N	309	

*** $p<0.01$

Perceived negative effects of pesticides and management implications

The results show that sixty-four percent of the respondents, in general, observed or faced some kind of negative effects or poisoning to humans, animals, or to the environment by the chemical pesticides they have used on their farms (**Table 7**). Specifically, 48% of the households observed a negative effect on human health, 33% on animals (livestock), 16% on wild animals, and 18% on water resources.

There is a statistically significant difference among the districts in the number of households who perceived negative effects of the chemical pesticides. The largest proportion (91%) of the households who perceived negative effects are from Gedeb Assasa while the least proportion (30%) are from Adea district. This could be related to the extent of pesticide uses among the districts. Districts, such as Assasa and Sinana are wheat belt areas that use mechanization and chemical pesticides, while Adea is known for teff production. Significant numbers of households in Sinana (86%) and Hetosa (85%) were also observed negative effects of pesticides on human and animal health as well as on the environment. A study conducted in Amhara regional state has also reported a significant financial and honeybee colony loss incurred as the result of side effects of pesticides on honeybees (Begna, 2015).

Table 7. Proportion of households who perceived the negative effects of pesticides

District	Any negative effect (%)	On human health (%)	On animal health (%)	On wildlife (%)	On water (%)
Etosa (*n*=97)	85	60	39	27	25
Assasa(*n*=99)	91	63	37	20	20
Sinana (*n*=107)	86	64	47	27	33
Adea (*n*=89)	30	26	22	15	20
Minjar (*n*=100)	50	33	25	17	15
Bora (*n*=81)	59	48	33	2	6
Dugda (*n*=202)	53	44	30	9	9
Total (*n*=775)	64	48	33	16	18
	$\chi^2(6) = 135.04$, $p = 0.000$	$\chi^2(6) = 52.04$; $p = 0.000$	$\chi^2(6) = 19.61$; $p = 0.003$	$\chi i^2(6) = 36.79$; $p = 0.000$	$\chi^2(6) = 38.34$; $p = 0.000$

More specific assessment of the pesticide effects on human health (incidence of immediate poisoning or discomfort) as a result of close contact of the individuals with chemicals was also done. About 68% of the households reported that they felt some sort of unidentified illness; headache (37%), skin irritation (23%), felt sickness (17%), and eye irritation (13%) after application of the pesticides (**Table 8**). Similarly, about 66% of the respondents in another study (Ocho *et al.*, 2016) reported that they had felt diverse symptoms of health problems after applying pesticides. A study conducted elsewhere in Ethiopia also showed an increased risk of respiratory system diseases related to young workers with the increased exposure to pesticides (Negatu *et al.*, 2017). Moreover, regular deaths of farmers because of unintentional exposure or misuse of pesticides were reported in Ethiopia and Ghana (Loha *et al.*, 2018).

Table 8. Health effects after pesticide application

Variables	Freq.	Percent
Felt discomfort/illness after pesticide application (n=775)	530	68
Reported feelings		
Head ache	198	37
Skin irritation	122	23
Felt sickness	88	17
Eye irritation	71	13
Vomiting	43	8
Other	8	2
Total	530	100

Pesticides are inevitable chemicals in farmers' daily life and it is imperative to focus on the practice of safety measures and management of potential pesticide risks. The causes of negative effects of pesticides could be related to gaps in information regarding pesticide handling and management or simply carelessness in the following safety measures or lack of resources, such as personal protective equipment (PPE). Although proper use of protective clothes/PPE during pesticides application is crucial to reduce the negative effects of pesticides mainly on human health, our study indicates that 62% of the farmers wore normal clothes when they sprayed the pesticides (**Table 9**), while about 23% wore (12% boots and 11% coveralls) partially protective equipment. The major reason for not wearing protective clothes for about 56% of the respondent is unavailability of the PPE, while 20% of the respondents have not been even aware of the existence of such clothes. In addition, the clothes have been too expensive to buy for 15% of the respondents (**Table 9**). Other studies have also indicated that 80% of the households in Jimma Zone (Ocho *et al.*, 2016) and 92% in Borena Zone of Ethiopia (Ligani, 2016) use normal clothes and shoes for spraying pesticides. A similar study has also reported that only 10% of individuals interviewed in the central part of Ethiopia had used full PPE during the spray of chemical pesticides (Negatu *et al.*, 2016). Our study also indicated that chemical pesticides are sprayed mostly by male household heads (65%) and sons (21%), implying high chemical hazards to male family members (results not displayed).

Table 9. Uses of protective cloths during chemical spray

What do you wear when spraying pesticides?	Freq.	Percent
Normal clothes	464	62
Boots	90	12
Coveralls	82	11
Gloves (specify material)	63	8
Normal eye glasses	3	0
Handkerchief around mouth	29	4
Goggle	2	0
Other	18	2
Total	751	100
Why not wear protective clothes?		
Too expensive	109	15
Not available	409	56
Uncomfortable	23	3
No awareness	147	20
Others	37	5
Total	725	100

Not only during the application but there are also some pesticide management problems with the storage mechanisms right after purchase in the study areas. There is a lack of knowledge and appropriate storage facilities at the household level. Nevertheless, our study shows that nearly 80% of the households do store pesticides in a separate place (**Table 10**). Yet, about 10% of the respondents store the pesticides somewhere in their house which could be hazardous for the family. However, nearly 90% of the households confirmed that they store the pesticides in places where children cannot access them.

Another important problem in pesticide management at the household level is with handling methods of expired pesticides. Our study shows that about 72% of the households know the shelf-life of the pesticides and 36% store them for the next season (**Table 10**). However, about 44% of households usually dispose of expired pesticides on the soil. However, about 74% of the respondents claim that they know how to handle pesticides and the most common source of advice for the majority (56%) of them was the district agricultural office. Neighbors and retailers are also other useful sources of information regarding how to handle pesticides. Unlike this, another study reported that more than 80% of the survey participants had never received information about the proper and safe disposal of pesticides (Agmas and Adugna, 2020).

Table 10. After purchase pesticides storage mechanisms

Pesticides storage places?	Freq.	Percent
In the kitchen	30	4
Anywhere in the house	75	10
In a separate place	610	79
Others	54	7
Total	769	100
How do you store pesticides you purchase?		
Like any other grocery in the house	18	3
Store where children could not have access	532	89
Other	47	8
Total	597	100
What do you do with expired pesticides?		
Continue using it	108	14
Ask advice of DAs	118	15
Dispose it off in the soil	337	44
Just store it	62	8
Sell/give to others	3	0
Other	141	18
Total	769	100
Know shelf life of the pesticides (n=775)	561	72
Store for next year/season (n=775)	280	36
Know how to handle pesticides (n=775)	576	74
Who gives advice about storage?		
Retailer	108	14
District office of agriculture	426	56
Neighbors	134	18
Research centers	5	1
Model farmers	15	2
Others	76	10
Total	764	100

Unsafe disposal of pesticide containers and leftovers is also another pesticide management problem in the study areas. Environmental, animal and human health effects of the pesticides could arise from inappropriate handling and disposal of pesticide containers. The households were asked what they did with the containers of the pesticides once they used the contents. The responses show 44% of the households either burnt or buried containers, 41% have thrown them out in an open field, 5% used them as a utensil at home, and another 5% put the containers in rubbish boxes or trash (**Figure 2**). Likewise, Ligani (2016) reported that about 65% of the respondents hang empty pesticide containers near the farm, while Ocho *et al.* (2016) described that 32% of the households re-use pesticide containers for other purposes. Similarly, about 64% of the respondents either sprayed the leftover chemicals on the soil or buried them and that could be another source of environmental pollution. In all cases, the expired pesticides, after spray leftovers and containers have not been properly disposed of and have inevitable environmental pollution, and human and animal health effects.

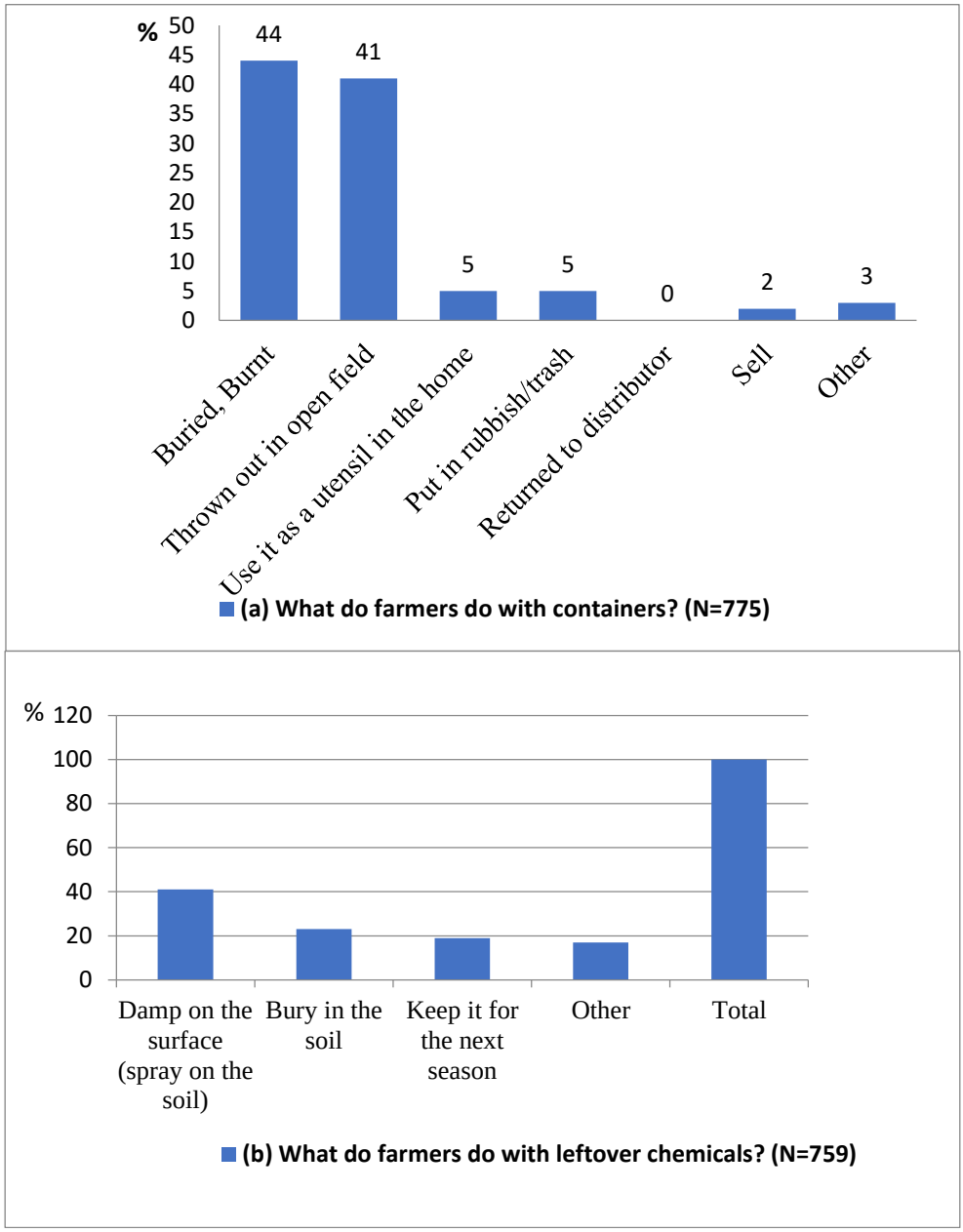

Figure 2. Disposal of pesticide containers and left overs

Access to information about pesticides safety measures and application procedures are believed to bring a difference in reducing pesticide hazards. Hence, the provision of information and guidance about pesticide use and management by suppliers is a useful first step to reduce pesticide effects. Our study identified that about 67% of the households were usually supplied with information or instructions/pamphlets during the purchase of the pesticides, but that information for about half of the households was in the language they don't understand

(**Figure 3**). About 62% of the households also responded that they read or got read the information on the pesticide containers and some 55% confirmed the presence of a written expire date on the containers. While some (22%) reported that they bought pesticides without labels. However, only 46% of the interviewed households followed the instructions they got during pesticide application. On the other hand, not more than 5% of sample households reported credit and extension services as constraints in pesticide utilization (**Table 11**). In addition the high prices of herbicides, insecticides, and fungicides were identified as a major constraint respectively by 42%, 45%, and 44% of the households. Limited availability of the chemicals was the second major constraint.

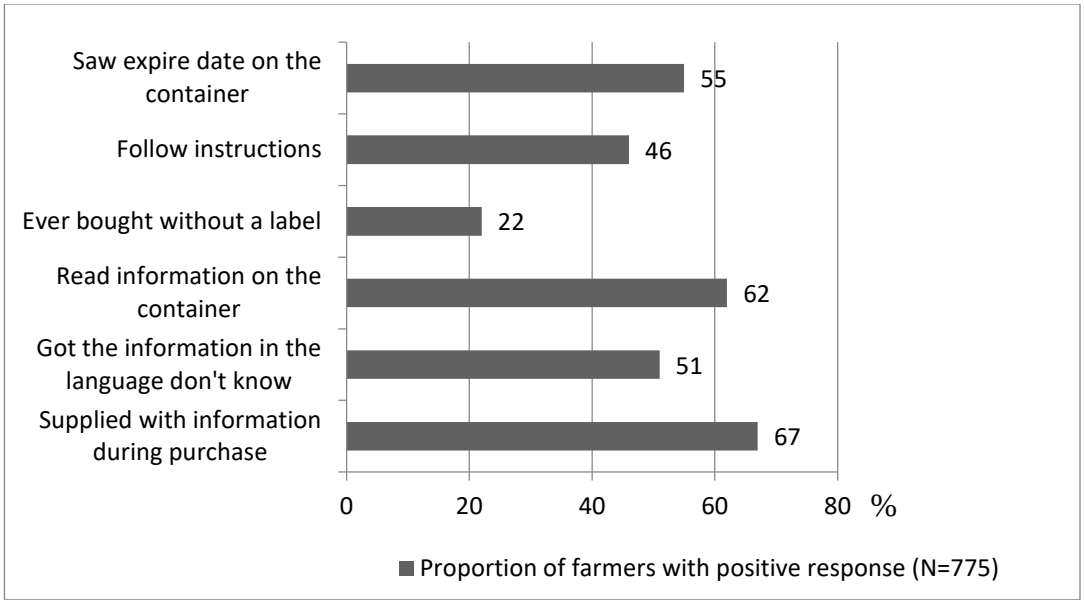

Figure 3. Access to information about pesticides safety and application procedures

Table 11. Major constraints households face in pesticide utilization (Percent)

Constraints/ problems	Herbicides (N=758)	Insecticides (N=748)	Fungicides (N=763)
High prices	42	45	44
Limited availability	27	25	29
Poor quality	13	14	15
Adulteration	1	0	0
Health problem	2	2	2
Lack of credit services	1	1	0
Lack of extension service	5	4	4
Other	9	8	5

Summary of Key Findings and Conclusions

Pesticides are crucial part of agriculture and human health worldwide irrespective of the potential risks and hazards they have. They support the production of the growing food supply and improve human health by controlling problematic pests. The overall aim of this study was to improve our understanding of the practices of pesticide uses, benefits, potential risks, and effects in selected areas of Ethiopia. We specifically assessed (1) farmers' knowledge of pesticide uses and benefits, (2) perceived environmental, human, and animal health effects, and (3) estimated the effects of pesticide application frequencies on wheat and teff yields using 775 farm household survey data. The results showed that about 99% of the households surveyed, in general use at least one type of the chemical pesticides, and 89%, 93%, 84%, and 15% of the households, in particular use pesticides for the controls of weeds, fungi, insects, and rodents, respectively, sometimes during a crop production season. In addition, a substantial number of farmers also use various traditional practices and new varieties as pest control methods. Well above 80% of households reported that the uses of chemical pesticides have solved the problems of crop pests and have also increased crop production and productivity on their farms. On the other hand, 64% of the respondents in general perceived some kind of negative effects or poisoning to humans, animals, or to the environment by the chemical pesticides they had used on their farms. Pesticides were sprayed mostly by male household heads (65%) and sons (21%), who do not take necessary precautions to reduce chemical hazards. However, nearly 90% of the households store the pesticides in places where children cannot access them. We found that 46% of the surveyed households have received training on pesticide uses and management, 63% have access to extension services. About 44% of the households usually dispose of expired pesticides on the soil, and 64% of the respondents either sprayed the leftover chemicals on the soil or buried them. Nevertheless, about 74% of the respondents in our study claimed that they know how to handle the pesticides. The OLS estimation results have also indicated that households who applied herbicides twice on wheat farms have obtained about 1.6 (t/ha) higher yield than those who have not used herbicides for wheat production. In addition, households who applied fungicides once, twice, and three times have obtained about 1.4, 1.0, and 1.2 (t/ha) higher yields than those who didn't use fungicides for wheat production. On the contrary, herbicide application frequencies on teff farms have not shown a statistically significant effect on teff yields. However, a necessary precaution has to be taken when interpreting these results as pesticide application usually depends on the occurrence of pests, weather, and climatic conditions.

In conclusion, pesticides are inevitable chemicals in farmers' daily life. Most (>80%) of the households surveyed were benefited and satisfied with the

effectiveness of the pesticides they use. The uses of herbicides and fungicides have also shown a yield advantage on wheat. Yet, a significant proportion of the respondents perceived negative effects or poisoning to humans, animals, or to the environment by the chemical pesticides they had used on their farms. Although there are extension and training services to more than half of the respondents on pesticide uses, it was not adequate either in quality or content to enable farmers take a necessary precaution during spraying. Most farmers don't use protective clothes or use trained workers to reduce pesticide hazards. Therefore, it is imperative to focus on the practice of safety measures and management to reduce potential pesticide risks. Well-established counseling and provision of paid services on the use of pesticides could reduce the negative effects. Furthermore, the traditional pest control methods which are in practice among farmers should be encouraged and the extent of their benefits in reducing impact of pests (by replacing pesticides) needs further investigation. We suggest further quantitative investigation on disposal mechanisms, health and environmental impacts of pesticides in Ethiopia.

References

Abate T. 1996. 'Ethiopian experience with pesticides-no foundation for food security.', *Pesticides News (United Kingdom) No. 33*, pp. 12-13.

Agmas B. and Adugna M. 2020. 'Attitudes and practices of farmers with regard to pesticide use in NorthWest Ethiopia.', *Cogent Environmental Science*. Cogent, 6. doi: 10.1080/23311843.2020.1791462.

Aktar W, Sengupta D and Chowdhury A. 2009. 'Impact of pesticides use in agriculture: their benefits and hazards', *Interdisciplinary Toxicology*, 2(1), pp. 1–12. doi: 10.2478/v10102-009-0001-7.

Amera Sahilu T. 2016. *Stewardship towards responsible management of pesticides* .

Ayalew A. and Kena K. 2011. *Application of NP Fertilizers for Better Production of Teff (Eragrostis tef (zucc.) trotter) on Different Types of Soils in Southern Ethiopia*, *Journal of Natural Sciences Research www.iiste.org ISSN*. Online. Available at: www.iiste.org (Accessed: 3 June 2021).

Begna D. 2015. 'Assessment of Pesticides Use and its Economic Impact on the Apiculture Subsector in Selected Districts of Amhara Region, Ethiopia', *Journal of Environmental and Analytical Toxicology*, 05(03). doi: 10.4172/2161-0525.1000267.

Cooper J. and Dobson H. 2007. 'The benefits of pesticides to mankind and the environment.', *Crop Protection*, 26(9), pp. 1337–1348.

Davison J, Creech E, and Laca M. 2010. *Response of Teff Grain Yields to Several Broadleaf Herbicides Applied at Three Different Growth Stages during 2009.*

Fianko JR. *et al.* 2011. 'Agrochemicals and the Ghanaian environment: a review', *Journal of Environmental Protection*, 2(03), p. 221.

Fikadu Z. 2020. 'Pesticides use, practice and its effect on honeybee in Ethiopia: a review', *International Journal of Tropical Insect Science*, pp. 473–481. doi: 10.1007/s42690-

020-00114-x.

Ligani S. 2016. 'Assessments of Pesticide Use and Practice in Bule Hora Districts of Ethiopia', *Haya: The Saudi Journal of Life Sciences Scholars*, 1(3), pp. 103–108. doi: 10.21276/haya.2016.1.3.4.

Loha KM. *et al.* 2018. 'Import, disposal, and health impacts of pesticides in the East Africa Rift(EAR) zone: A review on management and policy analysis', *Crop Protection*. Elsevier, pp. 322–331. doi: 10.1016/j.cropro.2018.06.014.

Manda N and Mohamed-Katerere J. 2006. 'Chemicals: our environment, our health', *Africa Environ Outlook*, (5), pp. 42–69.

Mengistie, BT, Mol, APJ and Oosterveer P. 2017. 'Pesticide use practices among smallholder vegetable farmers in Ethiopian Central Rift Valley', *Environment, Development and Sustainability*. Springer Netherlands, 19(1), pp. 301–324. doi: 10.1007/s10668-015-9728-9.

Nakka S. *et al.* 2019. 'Herbicide resistance: Development of wheat production systems and current status of resistant weeds in wheat cropping systems', *Crop Journal*. Elsevier B.V., 7(6), pp. 750–760. doi: 10.1016/j.cj.2019.09.004.

Negatu B. *et al.* 2016. 'Use of chemical pesticides in Ethiopia: A cross-sectional comparative study Onknowledge, attitude and practice of farmers and farm workers in three farming systems', *Annals of Occupational Hygiene*, 60(5), pp. 551–566. doi: 10.1093/annhyg/mew004.

Negatu B. *et al.* 2017. 'Occupational pesticide exposure and respiratory health: a large-scale cross-sectional study in three commercial farming systems in Ethiopia', *Thorax*, 72(6). doi: 10.1136/thoraxjnl-2016-208924.

Ocho FL. *et al.* 2016. 'Smallholder farmers' knowledge, perception and practice in pesticide use in South Western Ethiopia', *Journal of Agriculture and Environment for International Development*. Istituto agronomico per l'Oltremare, 110(2), pp. 307–323. doi: 10.12895/jaeid.20162.484.

Pingali PL. 2001. 'Environmental consequences of agricultural commercialization in Asia', *Environment and Development Economics*, 6(4). doi: 10.1017/S1355770X01000274.

Sisay MG. 2009. 'Ethiopian Floriculture and its Impact on the Environment: Regulation, Supervision and Compliance', *Mizan law review*, 3(2).