Ethiop. J. Agric. Sci. 32(2) 133-156 (2022)

Trends in Pesticide Use by Smallholder Farmers on 'Meher' Season Field and Horticultural Crops in Ethiopia

Tebkew Damte[1]

[1]*Ethiopian Institute of Agricultural Research, Debre Zeit Center, P. O. Box 32, Debre Zeit, Ethiopia; E-mail: tebkew@yahoo.com*

Abstract

Judicious use of pesticides in agriculture provides many important benefits and thus, they are used in the agricultural sector of Ethiopia. Trends in pesticide use between 2004/05 and 2019/20 'Meher' crop seasons by smallholder farmers on field and horticultural crops at national and regional levels were assessed. For each cropping season and each crop type national and regional data on the total number of households; the number of households who applied pesticides; the total area sown; and the area treated with pesticide were obtained from the annual report on farm management practices by the Central Statistical Agency (CSA) of Ethiopia. For each crop the compounded annual growth rate (CAGR) of pesticide use was estimated by transforming the exponential trend model to semi-logarithm trend function. The results reveal that the CAGRs for the number of households who applied pesticides on each of the field and horticultural crop and the area of each particular crop sprayed with pesticides were positive at both national and regional levels, which indicate an increasing trend in pesticide use on field and horticultural crops. At the national level, depending up on the type of crop, pesticide applicator households increased at CAGR of 4.16 to 19.62%. Similarly, pesticide treated area increased at CAGR of 2.12 to 34.06%. The CAGR for pesticide applicator households and pesticide treated area was not evenly distributed among crops and regions; however, pesticides were applied nearly on all crop types at both national and regional levels. Generally the proportions of pesticide applicator households and the proportion of pesticide treated area were greater in Oromia region followed by Southern Nation Nationality and Peoples region, Tigray region, and Amhara region. The occurrence of several new invasive pests; inclusion of pesticides as parcel of crop production technology packages in extension program; increase in agrarian population and the expansion of cultivated land; and susceptibility of high yielding improved crop varieties are among the main reasons for increased trend in pesticide use in Ethiopia. The detailed reasons for increased use of pesticides and limitations of the CSA's data are explained in the discussion part.

Keywords: Compounded annual growth rates, cereal crops, legume crops, vegetables, stimulant crops, beverage crops, root crops, fruit crops, smallholder farmers

Introduction

Agriculture is the backbone of Ethiopian economy because it is the livelihoods of 77% of the entire population in the country and contributes about one-third of the gross domestic product (NBE, 2021). This report also indicates that agriculture in

Ethiopia comprises of crop, animal farming, forestry, and fishery subsectors, which accounts for 61.1, 26.0, 8.6 and 0.2% of the total agricultural production. Because of the larger share of the crop subsector, in the past decade, there has been a strong intensification attempts to increase crop productivity and production as to alleviate the chronic food security problem in the country. The production intensification is based on the use of improved crop varieties; application of improved agronomic practices and fertilizers (Getachew and Aune, 2018).

However, crop productivity and production in the country is still very low. One of the major reasons for this low productivity and production is damage to crops by both regular and migratory pests. The major migratory pests that ravage crops throughout the history of Ethiopian agriculture are the locusts, the quelea birds (*Quelea quelea*), and the armyworms; while the regular (resident) pests are divers as the crops are. The amount of yield losses caused by the migratory pest outbreak is apparent; while the quantity of yield losses attributable to damage by regular (resident) pests under farmers' production conditions has not been clearly known. Nonetheless, it is believed that the annual pre- and post- harvest crop losses due to regular pests can reach up to 42% (Sharma *et al*., 2017). However, Tsedeke (1997) argues that because of the complexity and diversity of the small scale farming systems, the magnitude (and perhaps frequency) of pest outbreak is too rare when compared to the pest outbreaks in commercial farms.

In many developing countries agricultural development policies have resulted in increased use of chemical pesticides as a means to increase agricultural production (Ngowi, 2003). But in Ethiopia, improved crop varieties; agronomic practices; and fertilizers are dominant inputs that are used to increase crop production (Getachew and Aune, 2018), Consequently, although agricultural extension work in Ethiopia began in 1931 (Belay, 2003; Belay and Dawit, 2017) and the country is attempting to modernize the agricultural sector, traditional methods of pest managements are still the major techniques practiced by the majority of the smallholder farmers. For instance, weeds are controlled by crop rotation, hoeing, hand roguing, mowing, seed cleaning or oxen traction cultivation (which known locally as *shilshalo* or *biqbaqo*) (Nyssen *et al*., 2011). Hand picking, replanting, intercropping, crop rotation, beating with tree branches; spraying cow urine and dung; spraying botanical pesticides; and roguing infested plants are some of the pest management strategies used by smallholder farmers to manage insect pests. Moreover, washing seed with hot water; dressing seeds with cow or goat urine; rotating crops; draining excess water from fields; adjusting planting dates; site selection; and reducing plant population are the major traditional crop disease managements methods (Girma *et al.*, 2000; Adane *et al.*, 2008).

Pesticides are essential chemicals that are used to protect crop damage by pests and to improve agricultural output (Mahmood *et al*., 2016). In Ethiopia, the exact date and place where pesticide use on crops began is not known. However, Read (1941) (cited in Geremew and Jamornman, 2005) indicates that insecticides were applied on Ethiopian cotton as early as 1928; while Adefris (1956) and Belay (2016) stated that inorganic insecticides such as Arsenic 2% dust were used to control locust outbreaks in the early 1940s. Then, in the early 1960s Ethiopia began to import large quantity of pesticides and were introduced to smallholder farms, but most of the introduced pesticides were used in large scale state farms and for vector control (Loha *et al*., 2018; Mekuria *et al.* 2021). Following these large quantity importations, pesticide research that focused on screening and efficacy determination began in the early 1970s (Tsedeke, 1997). Since then many pesticides have been evaluated and effective ones recommended to control crop pests. However, pesticide uses in smallholder farming system are still limited to high value crops because of high price of pesticides and application equipment (Williamson *et al*., 2008). Thus, in the late 1980s Ethiopian smallholder farmers who used herbicides and other pesticides were < 5% and < 1%, respectively (Asmerom and Alber, 1994). Although the amount of pesticide use in the country is still very small, pesticide overuses and misuses are common throughout the country (Tebkew and Getachew, 2015).

In the late 1970s, Tessema *et al*., (1980) first gave general account of pesticide use in the agricultural sector of Ethiopia. Nearly two decades later, Tsedeke (1997) briefly discussed about pesticide regulations, research, and uses (import and consumption) in the country. Pesticide use trend is affected by time due to changes in pest problems; policy changes; expansion of cultivated lands; agrarian population growth; and other factors. For instance, according to Williams (2003) the pesticide market in Ethiopia was liberalized in 1995 and this had led to the mushrooming of large- and small- scale pesticide dealers. Consequently, the import and use of pesticides has shown steady growth since the early 1990s (Tsedeke, 1997; Mekuria *et al*., 2021). However, according to Tebkew and Getachew (2015) these pesticide dealers have no knowledge about the crops, pests, pesticides, and proper pesticide use. This in turn might have led to environmental pollution and contamination of food and feeds. For instance, pesticide residues have been detected in grain crops such as wheat (Daniel *et al*., 2011), tef (Seblework *et al.,* 2014), vegetable crops such as red pepper and green coffee (Seblework *et al.,* 2014); chat (*Catha edulis*) (Daniel *et al*., 2011); edible fishes (Ermias *et al.*, 2014; Yared *et al.*, 2014); human milk, goat milk and cow milk (Sosina *et al*., 2013; Habtewold *et al*., 2014) and cattle meat and organs (Bayessa and Attah, 2013). These facts raise concerns in the general public and highlight the need to examine trends in pesticide usage, which have not been assessed before at both national and regional levels. The decomposition of

aggregated pesticide use into regional level components will enable to determine the regions where most pesticide is used to produce crops. Therefore, the objective of this study was to assess the trend of pesticide use during Meher season in field and horticultural crops grown by smallholder farmers in Ethiopia.

Methodology

Description of regional states and crop growing seasons

Ethiopia has 11 regional states and two city administrations. The Oromia, Amhara, Southern Nation, Nationality and Peoples (SNNP), and Tigray are the major (ca. 95 to 99%) grain, vegetable and fruit producer regions; while Afar, Somali and Gambela regions are dominated by nomadic livestock producers. In the Benshangul-Gumuz (BeGu) region some crop species (maize, sorghum, ground nut, soybean, sesame and mango) are produced along with livestock. The Harari region produces chat *(Catha edulis)*, sorghum, vegetables and few fruit crops. The Sidama and the Southwest regions are recent divisions from the SNNP region and separate data are not available for them. The pesticide use data at regional level was taken from Oromia, Amhara, SNNP and Tigray and to some extent from BeGu regions.

In Ethiopia, the timing of pesticide application is divided into "Meher" season (sowing time June to August and harvesting time September to February) and "Belg" season (sowing time January to March and harvesting time March to August). Analyzable pesticide use data for *Belg* season are not available perhaps because of the erratic nature of rainfall in this season. Thus, for this study only the Meher season pesticide application by smallholder farmers was considered. Besides, the analysis focuses solely on pesticide use on field and horticultural crops because consolidated nationwide or regional data on pesticide use in non-agricultural sectors are not available.

Data collection approach and analysis

For each cropping season from 2004/05 to 2019/20 inclusive, and for each crop type national and regional data on the total number of households; the number of households who applied pesticides; the total area sown; and the area treated with pesticide were obtained from the annual report on farm management practices by the Central Statistical Agency (CSA 2005 to 2020) of Ethiopia. Each datum set was graphed to generate time plot to visualize the datum and investigate if there is any pattern exists overtime. Moreover, the Durbin-Watson Statistic was used as criterion to detect serial autocorrelation. These preliminary analyses revealed the presence of first and second order serial autocorrelation (regardless of the significance level) and non-linear relationship between time and all the variables

mentioned above. Consequently, the compounded annual growth rate (CAGR) of pesticide use were estimated by transforming the exponential trend model ($Y_i = \beta_0 \beta_1^{x_i} \varepsilon_i$) to semi-logarithm trend function, which is $Log_{10}Y_i = b_0 + b_1X_i$; where Y_i = number of households, households who applied pesticides on a particular crop, area under a particular crop or area treated with pesticides in year X_i; b_0 is the mean number of households, households who applied pesticides, area under a particular crop or area treated with pesticides in the 2004/05 crop season; b_1 the parameter that measures the CAGR per annum. A trend is detected when the b_1 is significantly different from zero (Gerrodette, 1987). Since exponential trend model was used, b_1 was converted to CAGR (%) as $(10^{b_1}-1)\times 100$. As indicated before, because of the presence of variable level of first and second order serial autocorrelation, each datum set was analyzed using Proc Autoreg of SAS. Furthermore, the percentage of area treated with or the percentage of households who applied pesticides in any one year was calculated as 100 * (total cropped area treated or total households who applied pesticides) / (total cropped area or total number of households who grow that particular crop). In some cases, particularly for pulse crops, vegetables, oil crops and root crops data were unavailable for some years because of high coefficient of variation. In such cases, the CAGR was estimated only if 13 data values were available.

Results

Cereal crops

Between 2004/05 and 2019/20 the major cereal crops produced were tef (*Eragrostis tef*), barley (food and malt types), wheat (bread and durum wheat), maize, sorghum, and finger millet (*Eleusine coracana*); while the minor cereal crops cultivated were *Aja* (*Triticum dicoccum*), Ethiopian oat (*Avena abyssinica*), triticale (*Triticosecale* Wittmack), rice (*Oryza sativa*), and pear millet (*Pennisetum glaucum*). Except for barley in which distinct trends were not detected in the total number of barely grower households and the total area under barley, the total number of households who grew and the total area under each major cereal crop had significantly increased at both national and regional levels (Tables 1 and 2). Among the minor cereal crops, utilizable data on total number of households and the area coverage were obtained only for *Aja* at national level and Oromia region. There was decreasing trend for Aja grower households and the area sown to *Aja* both at the national and regional levels.

The CAGRs for the number of households who applied pesticides on each of the major cereal crop and the area of each particular crop sprayed with pesticides were positive at both national and regional levels, which indicate an increasing trend in

pesticide use on major cereal crops (Table 3). However, the only exception to this increased pesticides use trend was the decreasing trend in pesticide user households and area of millet sprayed with pesticide in the SNNP region. Moreover, for all major cereals crops, the CAGRs for pesticide user households and the area sprayed with pesticide in Tigray and Amhara regions were greater than the national average and the corresponding CAGR values in Oromia and SNNP regions (Table 3). On the other hand, within same time span larger proportions of households in Oromia region had applied pesticides on tef, barley, and wheat than households in SNNP, Tigray and Amhara regions (Table 4). Consequently, the proportions of the area of each of these crops treated with pesticides were significantly greater in Oromia region than their counter parts, in increasing order, in SNNP, Tigray, and Amhara regions (Table 5). However, it should be noted that the Amhara region accounts for the larger proportion of major cereal crops producer households and the area under these major cereal crops in the country than Tigray, SNNP, and BeGu regions. For example, the Amhara region accounts for 37 to 40% and 31 to 39% of each of the total tef and barley grower households and the total area sown to tef and barley, respectively; while the Tigray and SNNP regions contributed about 9.8% and 16.0% of the total tef grower households and about 7.0% and 9.8%, respectively, of the national tef area. It means larger proportions of households in the Amhara regions did not apply pesticide on tef, barley and wheat crop and therefore most areas of each of these major crops in Amhara region were not sprayed with pesticides. The BeGu region accounted for less than 1% of the households that grow tef in Ethiopia and about 0.5% of the total area sown to tef in the country. Accordingly, the pesticide use by tef grower in the region was negligible.

At the national level, although the proportions of pesticide applicator households increased significantly for all crops, the proportions of pesticide user households on maize, sorghum and finger millet, on the average, were less than the proportions of pesticide users on tef, barley and wheat (Table 4). In the Tigray and Amhara regions relatively more households applied pesticides on maize, sorghum and finger millet than households in Oromia and SNNP regions. As a result the proportions of maize, sorghum, and finger millet area treated with pesticides were greater in the Tigray and Amhara regions than in Oromia and SNNP regions (Table 5). On the other hand, the BeGu region accounted for about 2.57% and 3.24% of the sorghum and millet grower households, respectively, and about 3.97% and 6.48% of the total area sown, respectively, to sorghum and millet in the country. Hence, pesticide used on both crops was negligible.

Table 1. Area (ha) sown to major cereal crops in 2004/05 and 2019/20 cropping seasons in main crop producer regions of Ethiopia

Region/ Nation	Crops and seasons											
	Tef		Barley		Wheat		Maize		Sorghum		Finger millet	
	2004/05	2019/20	2004/05	2019/20	2004/05	2019/20	2004/05	2019/20	2004/05	2019/20	2004/05	2019/20
Tigray	137,360	188,392	95,453	85,432	87,785	102,258	47,200	80,152	142,038	232,636	55,595	90,200
Amhara	852,307	1,156,131	375,912	321,515	392,722	578,034	285,242	532,483	411,949	641,614	148,002	236,125
Oromia	918,461	1,487,971	532,141	458,574	765,528	970,518	791,686	1,207,526	522,499	714,493	84,329	93,098
SNNP	210,055	241,009	84,936	84,034	131,485	134,475	207,410	339,963	92,009	105,256	4,767	6,618
Ethiopia	2,135,553	3,101,177	1,095,436	950,742	1,398,215	1,789,372	1,392,916	2,274,306	1,253,620	1,828,182	312,931	455,580

Source: compiled from CSA 2005 and 2020

Table 2. Number of households who grew major cereal crops in 2004/05 and 2019/20 crop seasons in the main crop producer regions of Ethiopia

Region/ Nation	Crops and seasons											
	Tef		Barley		Wheat		Maize*		Sorghum*		Finger millet*	
	2004/05	2019/20	2004/05	2019/20	2004/05	2019/20	2004/05	2019/20	2004/05	2019/20	2004/05	2019/20
Tigray	395,681	633,525	370,776	419,786	287,946	386,778	394,632	835,782	270,380	558,917	211,686	369,685
Amhara	1,839,987	2,659,496	1,475,667	1,196,450	1,252,127	1,932,885	1,780,595	2,979,969	895,059	1,234,881	428,306	793,841
Oromia	1,822,436	2,742,049	1,427,362	1,480,942	1,722,661	1,831,185	3,089,557	5,095,180	1,782,165	2,250,105	387,650	500,584
SNNP	767,677	1,077,959	597,800	809,504	626,620	715,807	1,199,744	2,223,614	549,905	727,019	50,632	93,342
Ethiopia	4,857,682	7,154,930	3,902,139	3,915,584	3,937,682	4,879,932	6,677,356	11,475,499	3,674,865	5,042,097	1,114,407	1,801,080

* Note: considerable number of households in Benshangul-Gumuz households produces maize, sorghum and finger millet, Source compiled from CSA 2005 and 2020

Table 3. Compounded annual growth rate (%) of households who applied pesticides on and pesticide treated area of major cereal crops between 2004/05 and 2019/20 cropping seasons in different regions of Ethiopia

Region/ Nation	Crops*											
	Tef		Barley		Wheat		Maize		Sorghum		Finger millet	
	HWAP	ATWP	HWAP	ATWP	HWAP	ATWP	HWAP	ATWP	HWAP	ATWP	HWAP	ATWP
Tigray	16.25	18.85	7.39	8.89	11.81	17.3	18.71	23.08	21.89	27.76	11.02	15.96
Amhara	13.88	13.45	6.12	7.23	10.08	9.02	18.22	25.14	18.03	20.92	16.33	13.03
Oromia	5.37	6.71	4.30	4.47	3.59	4.47	11.92	13.61	5.83	8.24	13.03	6.39
SNNP	2.90	2.73	3.73	3.11	2.59	2.42	14.29	15.61	5.75	9.29	-2.61	-2.18
Ethiopia	6.48	7.60	4.33	4.69	4.16	4.71	14.05	16.76	11.92	15.21	11.97	11.02

HWAP = Holders who applied pesticides, ATWP = Area treated with pesticides

Table 4. Proportion (%) of households who applied pesticides on major cereal crops in 2004/05 and 2019/20 crop seasons

Region/ Nation	Crop – season											
	Tef		Barley		Wheat		Maize		Sorghum		Finger millet	
	2004/05	2019/20	2004/05	2019/20	2004/05	2019/20	2004/05	2019/20	2004/05	2019/20	2004/05	2019/20
Tigray	4.67	33.78	4.55	10.62	3.15	15.71	1.20	16.47	1.46	31.55	2.61	20.47
Amhara	5.63	31.95	2.08	4.74	7.11	27.19	1.90	10.53	2.29	22.21	7.17	30.35
Oromia	43.35	57.45	21.72	42.05	27.91	70.30	2.33	7.98	3.16	5.56	9.99	12.86
SNNP	29.37	27.83	10.51	12.50	37.42	57.94	1.75	3.39	3.52	4.60	26.85	-
Ethiopia	23.47	41.27	10.78	21.12	27.89	43.35	2.06	8.25	2.76	12.22	8.01	22.30

Table 5. The proportion of area of major cereal crops sprayed with pesticides in 2004/05 and 2019/20 crop season

Region/ Nation	Crop – Season											
	Tef		Barley		Wheat		Maize		Sorghum		Finger millet	
	2004/05	2019/20	2004/05	2019/20	2004/05	2019/20	2004/05	2019/20	2004/05	2019/20	2004/05	2019/20
Tigray	3.19	34.65	2.78	7.36	1.39	10.49	0.79	19.18	0.88	32.48	1.67	18.55
Amhara	5.37	31.27	1.60	4.61	8.65	29.31	1.39	11.02	1.80	24.61	10.13	30.55
Oromia	43.79	63.70	21.28	50.71	56.11	77.64	2.52	11.21	3.18	7.23	11.39	14.15
SNNP	32.81	31.94	7.84	9.04	50.50	55.23	1.93	3.82	5.45	-	-	-
Ethiopia	24.50	47.19	11.74	27.49	38.00	56.39	2.09	10.02	2.44	16.29	9.03	23.80

Food legume crops

At the national level, there was no distinct trend in the number of households who grew faba bean *(Vicia faba* L.), field pea *(Pisum sativum* L.), chickpea *(Cicer arietinum* L.) and lentil *(Lens culinaris* Med.) between 2004/05 and 2019/20 crop seasons. Moreover, there was no discernible trend in the total area sown to each of these legume crops. On the other hand, the total number of households who produced haricot bean *(Phaseolus vulgaris* L.) and the total area sown to haricot bean had increased significantly at the national level.

At regional level, the trend in the number of households who grew a particular legume crop and the area under that particular legume crop were variable from region to region and from crop to crop. Thus, faba bean grower households and the area sown to faba bean in the Amhara and Tigray regions exhibited decreasing trend; while faba bean grower households and the area sown to faba bean increased in Oromia and SNNP regions. Similarly, the number of field pea producer households and the area sown to field pea did not change in Tigray, Amhara and Oromia regions; whereas, in SNNP region field pea grower households increased significantly; although there was no significant change in area sown. The number of chickpea grower households and the area under chickpea significantly decreased in Tigray and BeGu regions; while in Amhara region, the number of households who grew chickpea and the area under chickpea did not change. On the other hand, there was increasing trend in the number of households who grew and area sown to chickpea in Oromia and SNNP regions. In all regions there was no discernable change in the number of households who grew and the area sown to lentil. The total number of households who grow haricot bean significantly increased in Amhara, BeGu, Oromia and SNNP regions. On the other hand, increasing trend in area sown to haricot bean was evident only in the Amhara and Oromia regions.

At the national level the CAGRs for pesticide applicator households on faba bean, field pea, chickpea, lentil, grasspea (*Lathyrus sativus* L.) and haricot bean and the CAGRs for area of each legume crop sprayed with pesticides were positive (Table 6), which indicates increasing pesticide use trend in the production of these legume crops. On the average, faba bean, chickpea, lentil and grasspea had comparable but greater CAGRs for pesticide applicator households and pesticide treated area than field pea and haricot bean.

However, the proportion of pesticide applicator households and the proportion of pesticide treated area were on the average similar for these legume crops. Thus, between 2004/05 and 2019/20 crop seasons, the proportion of pesticide applicator households on lentil ranged from 1.00 to 16.27%, 1 to 9.97% on chickpea, 0.82 to 3.88% on haricot bean, 0.91 to 6.61% on field pea and 0.68 to 8.82% on faba

bean. The corresponding values for the proportion of area of each crop sprayed with pesticides were 1.04 to 31.20%, 1.21 to 27.80%, 0.29 to 6.08%, 0.96 to 10.08% and 0.39 to 14.01%.

Table 6. National compounded annual growth rate (%) for pesticide applicator households and pesticide sprayed area of legume crops between 2004/05 and 2019/20 crop season

Crop	Pesticide user households	Area sprayed with pesticides
Faba bean	18.6	23.03
Field pea	10.74	8.64
Chickpea	19.62	19.98
Lentil	14.92	21.48
Grasspea	19.51	21.39
Haricot bean	10.51	4.86

On the other hand, in all regions, the number of households who applied pesticides on legume crops and the area sprayed with pesticides increased significantly between 2004/05 and 2019/20 crop season; although there was variation among regions in the proportion of households who applied pesticides and the proportion of area of each legume crop treated with pesticide in each region. Thus, in Tigray region (CAGR = 20.89%), 0.64 to 13% of the faba bean grower households had applied pesticides on faba bean crop. About 0.31 to 7.00% of the households who grew faba bean in Amhara (CAGR =19.87%), 1.01 to 14% in Oromia (CAGR = 21.53%) and 0.64 to 4.00% in SNNP (CAGR =11.58%) had applied pesticide on 0.15 to 8.50%, 1.15 to 23.00% and 0.55 to 4.00% of the faba bean area, respectively.

In general pesticides were applied on field pea in the four regions; although the proportion of households who applied pesticide on field pea was at most 4% in Amhara, 14% in Oromia region and negligible in both Tigray and SNNP regions. The area treated with pesticide in Amhara, SNNP and Tigray regions was negligible, while in Oromia region depending up on season 1 to 28.4% of the field pea area was sprayed with pesticide.

Households who sprayed pesticide on haricot bean increased at CAGR of 12.69 and 8.32% per annum in Oromia and SNNP region, respectively. Moreover, haricot bean area treated with pesticide increased only in Oromia region by CAGR of 11.38%. Thus in Oromia region depending upon season 5.5 to 48% of the haricot bean grower had applied pesticide on 0.36 to 12% of the haricot bean area. In SNNP small proportion (0.18 to 1.26%) of the haricot bean growers had sprayed their haricot beans.

In chickpea and lentil, pesticide applicator households and the area treated with pesticides exhibited an increasing trend only in Oromia region. The households, who applied pesticide on chickpea, increased at CAGR of 17.22%, while chickpea area sprayed increased at CAGR 23.14%. Similarly, the households who applied pesticide on lentil and area treated with pesticides exhibited an increasing trend by CAGR of 14.10% and 13.89%, respectively.

The fenugreek *(Trigonella foenumgraecum* L.) and mung bean *(Vigna radiate* L.) are also treated with pesticides. However, the proportion of households who sprayed fenugreek and the proportion of fenugreek area treated with pesticides were negligible. Data on mung bean production is available beginning from 2013/14 crop season. The Amhara region is the major producer of mung bean and about 19 to 43% of the households had applied pesticides on 22 to 56% of the mung bean area. Data on pesticide use on soybean (*Glycine max*) and *gibto* (*Lupinus albus*) are not available.

Oil crops

Between 2004/05 and 2019/20 crop season oil crops cultivated in Ethiopia include noug (*Guzotia abyssinica*), linseed (*Linum usitatissimum*), rapeseed (*Brasica carinata*), groundnut (*Arachis hypogaea*), sesame (*Sesamum indicum)* and safflower (*Carthamus tinctorius)*. During this period pesticides were rarely applied on all of these oil crops. Thus, only 0.18 to 1.40% of the households had applied pesticide on 0.25 to 0.36% noug area, 0.49 to 3.36% of the households had sprayed pesticide on rapeseed; 0.25 to 12.27% of sesame grower households had applied pesticide on 0.15 to 19.4% of area sown to sesame. Moreover, about 3.15 to 13.65% of the households who grew linseed had sprayed 2.88 to 23.07of the linseed area. For all oil crops the disaggregated data on regional base were unusable to estimate CAGRs.

Stimulant and beverage crops

The major stimulant crops cultivated by smallholders were chat *(Catha edulis)* and coffee; while *gesho* (*Rhammus prinoides*) was the only beverage crop cultivated in most parts of Ethiopia. Between 2004/05 and 2019/20 crop season, the number of households who grew chat, coffee and *gesho* and the area under each crop had increased significantly. Moreover, the CAGRs for pesticide user households and the pesticide sprayed area on each of the three crops were positive, which indicates an increasing trend in pesticide use on stimulant and beverage crops production (Table 7). For coffee, the rate at which pesticide applicator household grew was less than the rate for chat and *gesho*. However, the proportions of pesticide applicator households on each crop and the proportions of each crop area that was sprayed with pesticides were very small. Thus, about 2.62 to 9.08% of chat growers, 0.45 to 2.64% of coffee growers and 0.45 to 2.45% *gesho* grower

had applied pesticides on 2.70 to 10.45%, 3.50 to 10.42% and 0.31 to 4.85% of chat, coffee and gesho area, respectively.

Table 7. National compounded annual growth rate (%) for pesticide applicator households and pesticide sprayed area of stimulant and beverage crops between 2004/05 and 2019/20 crop season

Crop	Pesticide user households	Area sprayed with pesticides
Chat	12.64	12.05
Coffee	5.71	12.31
Gesho	16.41	20.12

At regional level the trend for the number of households who applied pesticides on chat or coffee was positive in Oromia (CAGR = 11.84% or 3.47%) and SNNP (CAGR = 8.54% or 13.47%) regions. However, only in Oromia region (CAGR = 11.40%) there was discernible increasing trend in pesticide treated chat or coffee area. The proportion of chat grower households who applied pesticides in Oromia region ranged from 1.73 to 8.01% and 2.79 to 8.15% in SNNP region. Similarly on coffee, 0.46 to 1.07% of the coffee grower households in Oromia and 0.02 to 1.20% in SNNP region had applied pesticide on coffee area of 0.09 to 5.02% and on < 0.5%, respectively. The trend for the number of households who applied pesticides on *gesho* was positive in Oromia (CAGR = 8.64%) and Amhara (CAGR = 20.25%) regions. However, for both regions there was no distinct trend in pesticide treated area.

Leafy and fruit vegetables

Although tens of thousands households grow lettuce (*Lactuca sativa*) or Swiss chard *(Beta vulgaris L. var. cicla)* throughout the country, the total area under either of this crop is extremely small. Consequently, pesticides were rarely used on these crops.

At the national level, the number of households who grow head cabbage, Ethiopia kale, tomato, green pepper, and red pepper and the corresponding area for each crop had significantly increased between 2004/05 and 2019/20 crop season. Moreover, the CAGRs for households who applied pesticide on Ethiopian kale, head cabbage, tomato, green pepper and red pepper was positive (Table 8), which indicates increased use of pesticides on these crops. Consequently, 0.46 to 1.66% the households had applied pesticide on Ethiopian kale, 1.72 to 6.28% on head cabbage, 2.10 to 8.06% on tomato, 0.34 to 1.83% on green pepper, and 18.78 to 69.67% on red pepper. However, distinct trends in pesticide treated area were evident only for Ethiopian kale and red pepper. Thus 0.36 to 2.99% and 1.76 to 6.97% of the area under Ethiopian kale and red pepper, respectively were sprayed with pesticides. For the other crops the area treated with pesticides was highly variable among crop seasons (the estimates had very high coefficient of variation). Moreover, in each region tens of thousands households grew leafy and fruit vegetables on few hundred to few thousand hectares of land. Consequently, in

each region the proportion of households who applied pesticides and the proportion of leafy and fruit vegetable area treated with pesticides were very small.

Table 8. National growth rate (%) for pesticide applicator households and pesticide sprayed area of leafy and fruit vegetable crops between 2004/05 and 2019/20 crop season

crop	Pesticide user households	Area sprayed with pesticides
Head cabbage	14.34	-
Ethiopia Kale	7.57	12.36
Tomato	9.04	-
Green pepper	14.05	-
Red pepper	13.63	12.95

Root, tuber and corm vegetables

The important root crops in Ethiopia are beet root, carrot, sweet potato (*Ipomoea batatas*), cassava (*Manihot esculenta*) and Anchote (*Coccinia abyssinica*), while the economical tuber crops are potato (*Solanum tuberosum)* and yam (*Dioscorea* sp.). Taro (*Colocasia esculenta*) is probably the most widely cultivated corm crop in the country. Nationwide hundreds of thousands households are involved in beet root, carrot and yam production each on an area less than 5600 ha. Moreover, the proportion of households who applied pesticide varied among crop seasons and it ranges from 0.51 to 3.52% for beet root, 0.0 to 17.60% for carrot and none for yam producers. As a result the proportions of area treated with pesticides were negligible. Similarly, sweet potato and taro are produced by millions of households throughout the country on tens of thousands hectares. However, only 0.19 to 1.03% and 0.11 to 1.52% of the households who produce sweet potato and taro, respectively, had sprayed their crops with pesticides. In both crops the area sprayed with pesticide in any one year was less than 1%.

The number of households who produce potato in the country did not show significant change between 2004/05 and 2019/20 crop seasons; however, the area sown to potato had significantly increased at CAGR of 1.81%. Moreover, the number of pesticide user households and the potato area treated with pesticide had significantly increased by CAGR of 12.28% and 17.03%, respectively. Thus in 2004/05 crop season, 1.94% of the households who had grown potato had applied pesticide on 3.15% of the potato area. In the 2019/20 crop season, 11.16% of the households had sprayed pesticides on 26.95% of the area sown to potato.

Bulb crops

Onion (*Allium cepa* L.), shallot (*A. ascalonicum* auct. hort.), garlic (*A. sativum* L.) and leek (*A. porrum* L.) are the important bulb crops in Ethiopia. However, pesticide use data is available only for garlic and onion, which probably includes

the shallot. Between 2004/05 and 2019/20 crop seasons, the number of pesticide users on onion had increased at CAGR of 18.14% and the area treated with pesticides had increased at CAGR of 23.34%. There was high variation in the proportion of households who applied pesticides on onion from season to season. Therefore, depending upon season 1.34 to 15.15% of the households had sprayed their onion on 2.4 to 64.49% of the onion area. Similarly, between 2004/05 and 2019/20 crop season, the number of households who applied pesticides on garlic increased by CAGR of 19.37% and area treated with pesticide increased by CAGR of 34.06%. However, unlike other vegetable crops garlic is grown by millions of households on very small plots of land. For instance, in 2004/05 crop season about 1.90 million households had grown garlic on 0.014 million ha. About 0.95% of this area was sprayed with pesticides by 0.50% of the households. In the 2019/20 crop season area under garlic doubled and the number of households who grew garlic decreased to 1.34 million. Out of these households, 3.42% of them had applied pesticides on 19.49% of the garlic area.

Onion and garlic are produced in the Tigray, Amhara, Oromia, SNNP and BeGu regions and for each crop different levels of pesticide use had been reported from each region mainly from Amhara and Oromia regions. Therefore, about 2.00 to 23.90% households in the Amhara region and 1.91 to 19.11% in Oromia region had applied pesticides on onion. However, the area treated with pesticide varied from trace to 68.52% and trace to 73.83% in Amhara and Oromia regions, respectively. Similarly, about 0.16 to 2.94% households in the Amhara region had applied pesticides on trace to 8.12% of the garlic area and in Oromia region, trace to 0.61% of the garlic area was sprayed with pesticide by 0.81 to 11.70% of the households.

Fruit crops

Avocado (*Persea americana* Mill.), banana (*Musa* sp.), mango ((*Magifera indica* L.), papaya (*Carica papaya* L.), pineapple (*Ananas comosus* (L) Merr.), sweet orange (*Citrus sinensis)*, lemon (*C. limonum* L.), pomegranate (*Punica granatum*) and guava (*Psidium guajava*) are cultivated in different parts of the country. Moreover, few temperate crops (eg. apple and cherry) are being introduced to areas that have typical temperate climates. Each fruit crop is grown on few hundred square meters of land per household. For instance, the maximum average area per household per year for banana was about 200 m^2. The other fruit crops were grown on an average area much less than the average area of banana. Consequently, fruit crops like guava, lemon, pineapple, and papaya were rarely treated with pesticides. The proportion of households who applied pesticides on papaya, avocado, banana, mango and sweet orange was at most 0.71%, 0.54%, 1.05%, 1.05%, and 1.58%, respectively.

Discussion

Unavailability of pesticides use data has been considered as one of the major crop protection problems in developing countries (Tsedeke, 1997; Morales, 2002; Williamson *et al*., 2008). Thus, the pesticide use data provided by the Central Statistical Agency (CSA) of Ethiopia is a partial solution to the problem that existed since the country began to import and uses pesticides for crop pests and vector control. It is a partial solution because there are several limitations on the pesticide use data. The first limitation is that the pesticide use data do not indicate the purpose or the types of pesticides applied on each crop in each crop season. For instance, in each annual report CSA defines pesticide as insecticides and herbicides but in its datasheet (questionnaire) it defines pesticide as herbicides and fungicides, which casts doubt on the quality of the pesticide use data since CSA itself does not exactly know what it had collected. The second problem is that the amount and the frequencies of pesticide applications on each crop and crop season are not known. According to Tebkew and Getachew (2015) nearly half of the vegetable grower farmers in Ethiopia apply pesticides regularly. Moreover, Williamson *et al.* (2008) assert that repeated pesticide application is common in chat, grain legumes, cereal crops, and in storages. However, the current data source does not indicate the number of times an area was treated with pesticide. The total area treated with pesticide should be a product of the field area and the number of times it was sprayed with pesticides (Ewald and Aebischer, 2000). Moreover, Belay *et al.* (2017) indicated that some farmers apply pesticides at a rate greater than stated on the label. The third limitation is that the method of pesticide application is not known. For instance, Williamson *et al.* (2008) and Belay *et al*. (2017) reported that cocktail mixtures of pesticides are used by vegetable growers and grain producers. However, the CSA data do not take into account such methods of pesticide application. Thus, pesticide use data can be meaningful and accurate if the data collected include crop treated; area of crop grown; products used; amount used or rate of application (ι or kg per ha); area of crop treated; method of application (mixed or sole); and frequency of applications. This is because the data have value in many areas of research, legislation and agricultural support, and should not be seen as a simple statistical exercise in its own right (Thomas, 1999). Also it should be noted that the data provided by CSA, and hence in this paper, do not include the amount of pesticides used in commercial farms. Nor pesticides provided by the government or aid agents for the control of outbreak pests such as locusts, armyworm and *Q. quelea* birds.

Regardless of the difference in the proportions of pesticide applicator households and the proportion of pesticide treated area, pesticides are applied nearly on all crop types at both national and regional levels, which is contrary to the 1970s and

1980s when more than 95% of the smallholder farmers in Ethiopia had no access to pesticides (Tessema *et al*., 1980; Asmerom and Alber, 1994). Seneshaw *et al.* (2017) attribute increased use of herbicide in tef crop to proximity to urban centers, access to all-weather roads, and levels of local rural wages, which holds true for other crops too. Other reasons for increased use of pesticides on crops in Ethiopia are the following:

i. Policy change in import and distribution of pesticides. For example, prior to 1994, the Agricultural Input Marketing Corporation (AIMCO) used to have monopoly power over the distribution of fertilizers and agricultural chemicals (Asmerom and Alber, 1994). However, this pesticide market was liberalized in 1995 and consequently many large- and small - scale pesticide dealers were established throughout the country (Williamson, 2003; Tebkew and Getachew, 2015; Seneshaw *et al*., 2017; Mekuria *et al*., 2021), which had in turn increased the access to pesticides by smallholder farmers.

ii. The benefit derived from pesticide use. According to Pimentel *et al.* (1993) in the USA, for instance, a dollar invested in pesticide use returns three to five fold profits. Similarly in Ethiopia, Seneshaw *et al.* (2017) and Yohannis *et al.* (2018) have shown that with pesticide use crop yield increased and requirements for women and men labour decreased. The former researchers also indicated that application of herbicide in tef alone increased labor productivity by 9 to 18%.

iii. The soar up in cost of labor for hand weeding that led to increased use of pesticides, particularly herbicides. For instance, in the early 1970s the cost of hand weeding for a hectare of tef was 146 Birr (Birhanu and Tessema, 1984), which had increased to 3,900 Birr in 2018 (Abate *et al*., 2019). Often times it is stated that the price of pesticides and application equipment is out of the reach of small farmers (Williamson *et al*., 2008). On the contrary, some studies have shown that pesticides such as herbicides and their application are cheaper than the cost of hand weeding (Birhanu and Asfaw, 1984). For example, according to Samuel *et al.* (2019), in Jima zone, the average cost of slashing weeds in a coffee establishment phase is greater than 5000 Birr per ha, which is much greater than the cost (1158 Birr/ha) and application (416 Birr/ha) of herbicide. Moreover, Abate *et al.* (2019) affirm that in tef production hand weeding accounts for 35% of the total labor required for crop production. This holds true in the present day too and other crops since major agricultural transformation had not been taken place in most of the regions and the country at large.

iv. Agrarian population increase and the expansion of cultivated land. For example, between the 2004/05 and 2019/20 crop seasons, the households who

produced different crops and the area under major crops had increased tremendously (Tables 1 and 2). As a result the proportion of pesticide applicator households and the proportion of crop area treated with pesticide might have commensurate with the increases in agrarian population and crop area. However, one can argue that for most crops, the rate at which the number of crop producer households increased is equal or much greater than the rate at which the area under that particular crop had increased. Consequently, the average area per household per year sown to a particular crop might not have increased. For instance, in tef the CAGR at which the number of tef grower households grew was 2.30% and the CAGR at which area sown to tef increased was 2.35%. As a result, the average area sown to tef per household per year, which varied between 0.42 and 0.46 ha, had not changed between 2004/05 and 2019/20 crop season. The trend for area treated with pesticide per household per year was similar to that of the trend for area per household per year.

v. The inclusion of pesticides as parcel of crop production technology packages in extension program. Consequently, the extension agents push farmers to use pesticides (Tessema *et al.*, 1980; Belay *et al*., 2017). However, in some cases un-recommended pesticides are included in crop production technology packages. For instance, carbosulfan seed dressing and lambda cyhalothrin spray to control maize stalk borer (*Busseola fusca* (Fuller)) in maize and tef shoot fly (*Athrigonia* spp.) in tef, respectively, have been included in extension packages, although experiments demonstrated that seed dressing with carbosulfan (Tsedeke and Elias, 1998) and spraying lambda cyhalothrin were not effective and unnecessary (own observation).

vi. The necessity to control pests to increase quantity and quality of crop produces. This is because many high yielding improved varieties are susceptible to pests damage which lead to significant loss unless control measures implemented. For instance, in Ethiopia the leaf rust caused by *Puccinia triticina*, the stripe rust caused by *P. striiformis* f. sp. *tritici*, and the stem rust caused by *P. graminis* f. sp. *tritici* are major wheat diseases in most parts of the country. The recurrent occurrence of these major diseases and the frequent breakdown of resistant genes in improved varieties have forced Ethiopian wheat producer framers to use fungicides (Singh *et al.*, 2016). Furthermore, according to Williamson *et al.* (2008) farmers in the Amhara region of Ethiopia, suffer from severe pest incidence due to increased use of improved crop varieties, which had narrow genetic base than their counter landraces.

vii. The occurrence of several new invasive pests in different crops. Some examples include invasion of citrus crops by woolly whitefly (*Aleurothrixus*

floccosus (Maskell) in 2000 (Difabachew *et al.*, 2011); maize crop by fall armyworm (*Spodoptera frugiperda* JE Smith) in 2016 (Teshome et al., 2018); tomato by South American tomato moth (*Tuta absoluta* Meyrick) in 2013 (Ayalew, 2015); maize by maize lethal necrosis disease in 2014 (Mahuku *et al.*, 2015); and faba bean by faba bean "gall" (*Physoderma* sp) in 2010/2011 (Endale *et al.*, 2014); ginger by ginger bacterial wilt, *Ralstonia ~~S~~solansearum* (Smith) (Habetewold *et al.*, 2015); mango by mango fruit fly, *Bacterocera invadens* Drew in 2003 (Fekadu and Zenebe, 2015)*;* and mango by white mango scale, *Aulacaspis tubercularis* Newstead in 2010 (Ofgaa *et al.*, 2018).

The pesticide use trend for pest control was not evenly distributed among crops and regions. Compared to grain legume, oil, vegetable, stimulant and beverage crops and fruit crops; cereal crops on the average are treated with more pesticides. And among cereal crops, tef and wheat take the loin-share of the overall pesticide applied in the country, which might be associated with annual wider area coverage and the larger number of households involved in cereal crop production. Although the CSA data do not show which pesticides were applied in any of the crops, it is possible to infer from the available information on pests of each crop. For instance, tef has no major insect pests and diseases except the tef shoot fly (*Atherigona* spp.) and tef rust (*Uromyces eragrostidis*), which are known to attack tef occasionally. However, it is uneconomical to apply insecticide to control tef shoot fly (Tebkew, 2013) and fungicide to control tef rust (Woubit and Yeshi, 2005). Thus, herbicides are the major pesticides that are mostly used on tef in Ethiopia. In wheat, insect pest are not economically important throughout wheat growing regions of the country during the 'meher' season (Macharia *et al.*, 2016) but the three rust diseases mentioned earlier are major treats to wheat production, which indicates herbicides and fungicides are the major pesticides applied on wheat.

In Oromia region more proportion of households apply pesticides mainly on major crops and more proportion of crop area was sprayed with pesticide than the other regions. Although the exact reason why crop producers in Oromia region use more pesticide than the other region has not been investigated scientifically, the time at which extension began and the strong purchasing power of the households in Oromia region are the likely reasons for such differences. According to Belay (2003) and Belay and Dawit (2017) extension in Ethiopia began in 1931 in Ambo, which is situated in central Oromia and further strengthened extension work began in the early 1950s with the establishment of Imperial Ethiopian College of Agriculture and Mechanical Arts (IECAMA, now Haramaya University), which is located in eastern Oromia region.

In Ethiopia the major problems associated with pesticide use include unnecessary repeated applications; farmers perceptions that pesticides have functions other than controlling pests; wrong choice of pesticides; wrong time of application; spray water source (eg. use of water from puddle accumulated from runoff water); wrong empty pesticide disposal and use of band and/or obsolete pesticides (Williamson *et al.,* 2008; Tebkew and Getachew, 2015; Beyene *et al.*, 2016). This requires educating farmers on safe use pesticides; enforcing existing pesticide use laws and regulations; generating and extending alternative pest management technologies and selection of safer pesticides for use on need base.

Economic threshold level for major pests, particularly diseases and insect pests has not been established and pesticide application recommendations are on calendar base rather than actual infestation (insects) and infection (diseases) levels. The consequences of such calendar base pesticide use are resistance development to pesticides, risk to human health, destruction/ pollution of the environment and increased pesticide residues in food and feed. Although experimental evidences are lacking on the extent of pesticide resistance for all major crop pests in Ethiopia, the pod borer (*Helicoverpa armigera* Hubn.) (Geremew and Jamornmarn, 2005) and onion thrips (*Thrips tabaci* Lin.) (Belete *et al*., 2019) have developed resistance to endosulfan and lambda cyhalothrin, respectively.

The high risk to human health is primarily associated with the handling and use of pesticides because farmers often do not have adequate personal protective equipment (PPE) and they are reluctant to read labels (Tebkew and Getachew, 2015; Beyene *et al.,* 2016). Moreover, environmental pollution is a result of indiscriminate use of pesticides, accumulation of obsolete pesticides, empty container disposal and the amount of pesticide applied etc. However, it should be noted that the amount of pesticide, compared to other countries, applied on Ethiopian crop is much less than the amount applied in other countries. For example, according to FAO (2022) the average amount of pesticide use in Ethiopia is $<$ 1.0 kg/ha/year, while it is 15 kg/ha/ year in Israel.

Pesticide residues have been reported from cereal crops (Daniel *et al*., 2011; Seblewok *et al.,* 2014), vegetable crops (Seblework *et al.,* 2014); stimulant crops (Daniel *et al*., 2011; Seblework *et al.,* 2014) and different animal products (Bayessa and Attah, 2013; Sosina *et al*., 2013; Habtewold *et al*., 2014; Ermias *et al.*, 2014; Yared *et al.*, 2014). However, since Ethiopia has not enacted law that determines the maximum residue limit (MRL), also known as tolerance, it is difficult to decide whether or not the pesticide residue amounts reported are hazardous to human health. Nonetheless, other countries, mainly developed ones, have set MRL based on specific pesticide-crop combinations and they restrict/ ban import of commodities that have pesticide residue greater than their MRL level.

According to Hejazi *et al*. (2022) since different countries have different MRL, the export commodity is subjected to different sets of regulations that corresponds to the number of countries importing that commodity. Therefore, there is a need to reduce the pace of pesticide use growth on Ethiopian crops at least to meet the MRL of importer countries.

Conclusions

In contrast to findings in the 1970s and 1980s, pesticide use by smallholder farmers on crops in Ethiopia is increasing even though their use was not evenly distributed among crops and regions. Among crops cereal crops took the loin-share of the overall pesticide applied in the country., Compared to other regions; Oromia region on average contains more proportion of households that apply pesticides and more proportion of crop area sprayed with pesticides. However, the quality of available CSA pesticide use data has severe limitations. Pesticides are critical inputs in agriculture to produce enough food to feed the exploding human population and provide raw materials for industries. However, they have to be applied judiciously in order to reduce their undesirable side effects. The current study indicated that there is an increase in use of pesticides in Ethiopian agriculture in the past 15 years. This will have effect on health of human and the environment, food quality and can affect agricultural commodity export. Therefore, it is necessary to reduce the pace at which pesticide use rate increases through provision of safe and effective alternative pest management technologies, including integrated pest management. Moreover, improving the quality and reliability of the pesticide used data collected by CSA; developing nationwide pesticide use monitoring schemes, and generating alternative pest management technologies are focus areas of interventions in the future.

Acknowledgments

The author acknowledges an anonymous reviewer for her/his invaluable suggestions and comments. The work was financially supported by the Ethiopian Institute of Agricultural Research.

References

Abate Bekele, Solomon Chanyalew, Tebkew Damte, Nigussu Husien, Yazachew Genet, Kebebew Assefa, Demeke Nigussie, and Zerihun Tadele. 2019. Cost-benefit analysis of new tef (*Eragrostis tef*) varieties under lead farmers' production management in the central Ethiopia. *Ethiop. J. Agric. Sci.* 29(1): 109-123

Adane Tesfaye, Ermias Abate and Melkamu Ayalew. 2008. Horticultural crops pest status, distribution and their indigenous management techniques in the Amhara region. pp. 259-266. In: Lemma Dessalegn, Endale Gebre, H/Michael Kidane

Mariam, Zenebe Wouldu, Terefe Belihu. Asfaw Zelleke and Lakew Belayneh (Eds) Proceedings of the first conference of the Ethiopian Horticultural Science Society (EHSS), 23-24 March 2006, Addis Ababa, Ethiopia.

Adefris Behailu. 1956. Desert locust control (in Amharic). Ministry of Agriculture, Addis Ababa, Ethiopia

Asmerom Kidane and Abler DG. 1994. Production technologies in Ethiopian agriculture. *Agric. Econ.* 10: 179-191

Ayalew G. 2015. Efficacy of selected insecticides against the South American tomato moth, *Tuta absoluta* Meyrick (Lepidoptera: Gelechiidae) on tomato in the central Rift Valley of Ethiopia. *Afr. Entomol*. 22(2): 410-417

Bayessa Letta and Attah LE. 2013. Residue levels of organochlorine pesticides in cattle meat and organs slaughtered in selected towns in West Shoa Zone, Ethiopia. *J. Environ. Sci. Health.* 48(1): 23-32. DOI: 10.1080/03601234.2012.693866

Belay Kassa. 2003. Agricultural extension in Ethiopia: the case of participatory demonstration and training extension system. *J. Soc. Dev. Afr.* 18 (1): 49 - 83

Belay Kassa and Dawit Alemu. 2017. Agricultural Research and Extension Linkages: Challenges and Intervention Options. *Ethiop. J. Agric. Sci.* 27(1): 55-76

Belay Mengistie. 2016. Environmental Governance of Pesticides in Ethiopian Vegetable and Cut Flower Production. PhD thesis, Wageningen University, Wageningen, Netherlands ISBN: 978-94-6257-949-1 DOI: http://dx.doi.org/10.18174/391632

Belay Mengistie, Mol APJ, and Oosterveer P. 2017. Pesticide use practices among smallholder vegetable farmers in Ethiopian Central Rift Valley. *Environ. Dev. Sustain*. 19:301–324. DOI 10.1007/s10668-015-9728-9

Belete Negash, Ferdu Azerefegne and Gashawbeza Ayalew. 2019. Farmers' insecticide use practice and species composition and abundance of thrips species (Thysanopter: Thripidae) on onion in the Rift Valley of Ethiopia. *Afr. J. Agric. Res.* 14(32): 1537-1543. DOI: 10.5897/AJAR2019.14010

Beyene Negatu, Kromhout H, Yalemtshay Mekonnen and Vermeulen R. 2016. Use of chemical pesticides in Ethiopia: A cross-sectional comparative study on knowledge attitude and practice of farmers and farm workers in three farming Systems. *Ann. Occup. Hyg.* 1–16. DOI:10.1093/annhyg/mew004

Birhanu Kinfe and Tessema Megenasa. 1984. Frequency of hand weeding on weed control and yield of tef (*Eragrostis tef* (Zucc.) Trotter). *Ethiop. J. Agric. Sci*. VI (2):88-101

Birhanu Kinfe and Asfaw Zeleke. 1984. The effect of soil acting herbicides versus hand weeding on weed control and yield of tef. *Ethiop. J. Agric. Sci.* VI (1): 35-50

CSA (Central Statistical Agency). 2005 to 2020. Agricultural Sample Survey: report on farm management practices of the respective year. Addis Ababa, Ethiopia

Daniel Daba, A. Hymete, A.A. Bekhit, A.M.I. Mohamed, and A.A.B. El-Din. 2011. Multi residue analysis of pesticides in wheat and khat collected from different regions of Ethiopia. *Bull. Environ. Contam. Toxicol.* 86:336–341. DOI 10.1007/s00128-011-0207-1

Difabachew Belay, Abebe Zewdu, and Foster JE. 2011. Ecology and management of the woolly whitefly (Hemiptera: Aleyrodidae), a new invasive citrus pest in Ethiopia. *J. Econ. Entomol.* 104(4): 1329-1338. Doi.org/10.1603/EC11017

Endale Hailu, Gezahegn Getaneh, Tadesse Sefera, Nigussie Tadesse, Beyene Bitew Anteneh Boydom, Daniel Kassa and Tamene Temesgen. 2014. Faba Bean Gall; a new threat for faba bean (*Vicia faba*) production in Ethiopia. *Adv Crop Sci. Tech* 2: 144. DOI: 10.4172/2329-8863.1000144

Ermias Deribe, B.O. Rosseland, R. Borgstrøm, B. Salbu, Zinabu Gebremariam, Elias Dadebo, L. Skipperud and O.M. Eklo. 2014. Organochlorine Pesticides and Polychlorinated Biphenyls in Fish from Lake Awassa in the Ethiopian Rift Valley: Human Health Risks. *Bull. Environ. Contam. Toxicol.* DOI 10.1007/s00128-014-1314-6

Ewald JA, and Aebischer NJ. 2000. Trends in pesticide use and efficacy during 26 years of changing agriculture in southern England. *Environ. Monito. and Assessment* 64: 493–529

Fekadu Massebo and Zenebe Tefera. 2015. Status of *Bactrocera invadens* (Diptera: Tephritidae) in Mango-Producing Areas of Arba Minch, Southwestern Ethiopia. *J. Insect Sci.* 15(3): 2015; DOI: 10.1093/jisesa/ieu166

FAO (Food and Agriculture Organization of the United Nation). 2022. Pesticides use, pesticides trade and pesticides indicators: Global, regional and country trends, 1990–2020. FAOSTAT ANALYTICAL BRIEF 46. Rome, Italy

Geremew Terefe and Jamornmarn S. 2005. Susceptibility of African bollworm (*Helicoverpa armigera*) populations to synthetic insecticides in Ethiopia. *Pest Mgt. J. Eth.* 9: 29-38

Gerrodette T. 1987. A power analysis for detecting trends. *Ecology* 68(5): 1364-1372

Getachew Sime and Aune JB. 2018. Sustainability of Improved Crop Varieties and Agricultural Practices: A Case Study in the Central Rift Valley of Ethiopia. *Agric. 8*(11), 177; DOI : 10.3390/agriculture8110177

Girma Tesfahun, Wondimu Bayu and Adane Tesfaye. 2000. Indigenous crop pest management techniques in Welo. *Pest Mgt. J. Eth* . 4(1&2): 97-103

Habtewold Deti, Hymete A, Bekhit AA, Mohamed AMI, and El-Din Bekhit AA. 2014. Persistent organochlorine pesticides residues in cow and goat milks collected from different regions of Ethiopia. *Chemosphere* 106: 70–74. DOI: 10.1016/j.chemosphere.2014. 02.012

Habetewold Kifelew, Bekele Kassa, Kasahun Sadessa and Tariku Hunduma. 2015. Prevalence of bacterial wilt of ginger (*Z. Officinale*) caused by *Ralstonia solansearum* (Smith) in Ethiopia. *Int. J. Res. Stud. Agric. Sci.* 1 (6): 14-22.

Hejazi M, Grant JH and Peterson E. 2022. Trade impact of maximum residue limits in fresh fruits and vegetables. *Food Policy* DOI: 10.1016/j.foodpol.2021.102203

Loha KM, Lamoree M, Weiss JM, and de Boer J. 2018. Import, disposal, and health impacts of pesticides in the East Africa Rift (EAR) zone: A review on management and policy analysis. *Crop Protec.* 12: 322-331

Macharia M, Tebkew Damte, Agum W, and Njuguna M. 2016. Incidence and distribution of insect pests in rain-fed wheat in Eastern Africa. *African Crop Science Journal*. 24: 149 – 155. DOI: http://dx.doi.org/10.4314/acsj.v24i1.17S

Mahmood I, Sameen RI, Kanwal S, Alvina G, and Khalid RH. 2016. Effects of pesticides on the environment. In-Plant, soil and microbes, pp. 253-269. *Springer, Cham*, 2016. https://doi 10.1007/978-3-319-27455-3_13

Mahuku G, Wangai W, Sadessa K, et. al. 2015. First Report of Maize chlorotic motle virus and Maize Lethal Necrosis on Maize in Ethiopia. *Plant Dis.* 99(12): 1870, doi.org/10.1094/PDIS-04-15-0373-PDN

Mekuria Teshome Mergia, Ermias Derbe Weldemariam, O.M. Eklo, Girma Tilahun Yimer. 2021. Small-scale Farmer Pesticide Knowledge and Practice and Impacts on the Environment and Human Health in Ethiopia. *J. H & P.* 11(30): 1 – 19.

Morales H. 2002. Pest management in traditional tropical agroecosystems: Lessons for pest prevention research and extension. *Integr. Pest Manag. Rev.* 7: 145–163,

NBE (National Bank of Ethiopia). 2021. Annual report 2020/21. Addis Ababa, Ethiopia

Ngowi AVF. 2003. A study of farmers' knowledge, attitude and experience in the use of pesticides in coffee farming. *Afr Newsletter Occup Health Safety*; 13: 62–64.

Nyssen J, Govaerts B, Tesfay Araya, Cornelis WM, Bauer H, Mitiku Haile, Sayre K and Deckers J. 2011. The use of the marasha ard plough for conservation agriculture in Northern Ethiopia *Agron. Sustain. Dev.* 31: 287-297. DOI: 10.1051/agro/2010014

Ofgaa Djirata, Emana Getu and Ruth KG. 2018. Population dynamics of white mango scale, *Aulacaspis tubercularis* Newstead (Hemiptera: Diaspididae) in western Ethiopia. *Afr. J. Agric. Res.* 13(31): 1598-1605. DOI: 10.5897/AJAR2018.13176

Pimentel D, McLaughlin L, Zepp A, et al. 1993. Environmental and economic effects of reducing pesticide use in agriculture. *Agri., Ecos. and Environ.* 46 : 273-288

Read PD Jr. 1941. Cotton in Ethiopia, Eritrea and the Somalilands. In: Cotton in Africa. National Cotton Council of America. Memphis 1, Tennessee, USA.

Samuel Diro, Beza Erko, and MesayYami M. 2019. Cost of Production of Coffee in Jimma Zone, Southwest Ethiopia. *Ethiop. J. Agric. Sci.* 29(3): 13-28

Seblework Mekonen, Argaw Ambelu and Spanoghe P. 2014. Pesticide residue evaluation in major staple food items of Ethiopia using the quechers method: a case study from the Jimma Zone. *Environ. Toxicol. Chem.* 33 (6): 1294–1302

Seneshaw Tamru, Minten B, Dawit Alemu and Fantu Bachewe. 2017. The rapid expansion of herbicide use in smallholder agriculture in Ethiopia: Patterns, drivers, and implications. *The Eur. J. Dev. Res.* DOI:10.1057/s41287-017-0076-5

Sharma S, Kooner R and Arora R. 2017. Insect Pests and Crop Losses. pp. 45-66. In: Arora R. and S. Sandhu (eds) Breeding Insect Resistant Crops for Sustainable Agriculture. Springer Nature Singapore Pte Ltd., Singapore

Singh RP, Singh PK, Rutkoski J, et al. 2016. Disease impact on wheat yield potential and prospects of genetic control. *Annu. Rev. Phytopathol*. 54: 303–322. Doi: 0.1146/annurev-phyto-080615-095835

Sosina Gebremichael, Tarekegn Birhanu, and Dejene Tessema. 2013. Analysis of organochlorine pesticide residues in human and cow's milk in the towns of Asendabo, Serbo and Jimma in South-Western Ethiopia. *Chemosphere* 90: 1652–1657. doi.10.1016/j.chemosphere. 2012.09.008

Tebkew Damte T**.** 2013. Insect pest management research in tef. pp. 171-192. In: Kebebew Assefa, Solomon Chanyalew and Zerihun Tadele (eds) Achievements and prospects of tef improvement. Proceedings of the second international workshop, Nov. 7-9, 2011, Debre Zeit, Ethiopia

Tebkew Damte and Getachew Tabor. 2015. Small-scale vegetable producers' perception of pests and pesticide uses in East Shewa zone, Ethiopia. *Int. J. Pest Manag*. doi: 10.1080/09670874.2015.1036822

Teshome Kumela, Simiyu J, Birhanu Sisay, Likhayo P, Esayas Mendesil, Gohole L. and Tadele Tefera. 2018. Farmers' knowledge, perceptions, and management practices of the new invasive pest, fall armyworm (*Spodoptera frugiperda*) in Ethiopia and Kenya. *Int. J. Pest Manag.* 65: doi.org/10.1080/09670874.2017.1423129

Tessema Megenasa, Taddese Gebre-Medhin and Tsedeke Abate. 1980. A review of the state of agricultural pesticides use in Ethiopia. *Eth. J. of Agri. Sci.* II (1): 29-37.

Thomas MR.1999. Guidelines for the collection of pesticide usage statistics within agriculture and horticulture. Organisation for Economic Cooperation and Development, Paris (available on line)

Tsedeke Abate. 1997. Pesticides in Ethiopian agriculture: a researcher's view. *Pest Mgt. J. Eth* 1(1&2): 49-55

Tsedeke Abate and Elias Worku. 1998. Carbosulfan seed dressing, sowing date, and genotype effects on maize stalk borer. *Pest Mgt. J. Eth.* 2 (1&2): 85-89

Williamson S. 2003. Pesticide provision in liberalized Africa: out of control? Agricultural Research and Extension Network, Network Paper No. 126

Williamson S, Ball A and Pretty J. 2008. Trends in pesticide use and drivers for safer pest management in four African countries. *Crop Protec.* 27: 1327-1334

Woubit Dawit and Yeshi Andnew. 2005. The study of fungicides application and sowing date, resistance, and maturity of *Eragrostis tef* for the management of teff rust [*Uromyces eragrostidis*]. *Can. J. Plant Pathol*. 27: 521–527

Yared Yohannes, Ikenaka Y, Saengtienchai A, Watanabe KP, Nakayama SMM and Ishizuka M. 2014. Concentrations and human health risk assessment of organochlorine pesticides in edible fish species from a Rift Valley lake, Lake Ziway, Ethiopia. *Ecotoxicol. Environ. Saf.* 106: 95–101. DOI: 10.1016/j.ecoenv.2014.04.014

Yohannis Mulu Tessema, Asafu-Adjaye J, and Bekele Shiferaw. 2018. The impact of conservation tillage on maize yield and input demand: the case of smallholder farmers in north-west Ethiopia. *Aust. J. Agric. Econ*. 62: 636–653