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PESTICIDE USE PATTERN AND INSECTICIDE RESIDUE LEVELS IN TOMATO (*LYCOPERSICUM ESCULENTUM* MILL.) IN SOME SELECTED PRODUCTION SYSTEMS IN GHANA

By

PETER MAXWELL BINEY
B.Sc Agriculture (Crop Science)
UNIVERSITY OF GHANA, LEGON

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DECLARATION

I do hereby declare that except for references to work of other scholars which have been duly acknowledged, this thesis is my own original research, which has neither been presented in whole nor in part to any other works for the award of a degree.

.....
Peter Maxwell Biney
(Student)

.....
Dr. E. O. Owusu
(Supervisor)

.....
Dr. Philip O. Yeboah
(Supervisor)

.....
Dr. D. Obeng-Ofori
(Supervisor)

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ABSTRACT

A survey of 120 tomato farmers under two production systems was carried out at Tono and Vea in the Upper East region, Derma and Techimentia in the Tano district of the Brong Ahafo region to assess farmers' knowledge of insect pest problems, production systems and pest management practices with emphasis on pesticide use patterns. Residue levels of Lindane, Endosulfan and Chlorpyrifos insecticides in harvested tomato fruits from Derma, Techimentia, Tono and Vea areas were determined by Gas Chromatography and compared with FAO/WHO MRLS's

The major insect pests of tomato were the fruitborers *Helicoverpa armigera* (Hubner) and the variegated grasshopper *Zonocerus variegatus* (L). Pests such as aphids *Aphids gossypii* Glover, mirids *Nesidiocoris tenuis* Reuter, whiteflies *Bemisia tabaci* Genn. and African-mole cricket *Gryllotalpa africana* were identified but it was obvious that farmers lacked knowledge on aspects of pest biology, damage and management. Yield losses perceived by farmers to be caused by pests ranged from 5% - 40%. In the Tano district, traditional tomato varieties such as Power, Reno, Yokohama and Italy were cropped from uncertified seed source. About 84.6% of tomato farmers in the Upper East region cropped certified, exotic and high yielding varieties. Farmers did not practice integrated pest management. Highly hazardous insecticides recommended for the control of cocoa and cotton pests were used on tomatoes. These included Deltaphos 262 EC (Deltamethrin and Triazophos), Cypercal P 186 EC (Cypermethrin and Profenefos), Decis D 312 EC (Deltamethrin and Chlorpyrifos methyl), Polythrin 336 EC (Cypermethrin and Chlorpyrifos methyl), K D (Lamda-cyhalothrin and Chlorpyrifos methyl), Thiodan 50 EC (Endosulfan), Thiodan 35 EC/ULV (Endosulfan) and "Gammalin" 20 EC (Landane).

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About 23.1% and 13.3% of the insecticides used by farmers in the Brong Ahafo and Upper East regions respectively were organochlorines. Fungicides such as Topsin (Thiophanate methyl), Benlate (Benomyl), Ridomil (Metalaxyl), Dithane (Mancozeb) and the Copper base products were applied more in the Brong Ahafo region. In most cases, contact and systemic fungicides were not used to control specific diseases, but for luxuriant vegetative growth and cosmetic value. The average frequency of application was 10 – 12 and 4 – 6 times of cocktail of pesticides in the Brong Ahafo and Upper East regions, respectively based on calendar spraying at 3 – 7 days intervals.

Studies into residue levels of Lindane, Endosulfan and Chlorpyrifos insecticides applied on tomato revealed that fruits sampled from Tano district had residue levels of Lindane ranging from 0.005 mg/kg to 0.712 mg/kg. Residue levels of Alpha endosulfan ranged from 0.014 mg/kg to 0.126 mg/kg. The residues of both insecticides were below Maximum Residue Limits (MRLs') recommended by FAO/WHO. Chlorpyrifos residues analysed in tomatoes from Upper East region ranged from 0.019 mg/kg to 0.937 mg/kg. About 25% of tomato samples analysed had residue levels exceeding FAO/WHO MRL's check for Chlorpyrifos at 0.5 mg/kg (FAO/WHO, 1993). The findings underscore the need for routine monitoring of pesticide residue levels and improved practice of pesticide use to ensure food safety

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DEDICATION

This thesis is dedicated to my dear wife Sally Akua Adubea Biney (Mrs), for her love, support and encouragement in the course of this work.

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LIST OF ACRONYMS

AEA	Agricultural Extension Agent
ADI	Acceptable Daily Intake
ai	Active Ingredient
ARPPIS	African Sub-Regional Post Graduate Programme in Insect Science
BAR	Brong Ahafo Region
Bt	*Bacillus thuringiensis*
DBM	Diamond back-moth
EC	Emulsifiable Concentrate
e.g	Example given
EPA	Environmental Protection Agency
FAO	Food and Agricultural Organization
FASCOM	Farmers Services Company
FFS	Farmers' Field School
FIG	Figure
g	Grammes
GAP	Good Agricultural Practice
GTZ	German Technical Co-operation
Ha	Hectares
ICOUR	Irrigation Company of Upper Region

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ICP	Integrated Crop Protection
IPM	Integrated Pest Management
MoFA	Ministry of Food and Agriculture
MRL's	Maximum Residue Levels
MT	Metric Tonnes
NARP	National Agricultural Research Project
NRI	Natural Research Institute
OC	Organochlorine
OP	Organophosphorus
PHI	Pre-Harvest Intervals
PPMED	Policy, Planning, Monitoring and Evaluation Directorate
PPRSD	Plant Protection and Regulatory Services Directorate
SP	Synthetic pyrethroid
T	Tonnes
UER	Upper East Region
ULV	Ultra Low Volume
UN	United Nations
UNDP	United Nation Development Programme
WHO	World Health Organization
WP	Wettable Powder

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CHAPTER 1

1.0 GENERAL INTRODUCTION

Tomato *Lycopersicum esculentum* Mill is an important food crop and source of income for many small-scale farmers in Ghana. It accounts for a good part of the total vegetable consumption in Ghana and makes up 38% of the vegetable expenditure of Ghanaians on the average (Ghana Statistical Service, 1995). Total national tonnage is estimated to be 212,800 tons (Nurah, 1999) (Table 1). Yields of 16.6 tons/ha are possible in the Upper East region of Ghana and as low as 6.0 tons/ha are reported in the forest/transitions zones of Brong Ahafo and Ashanti regions (Nurah, 1999; Tweneboah, 1998). Low yields can be attributed to unfavourable environmental conditions like high temperature, pest and diseases occurrence and improper management practices (Yvon, 1997).

According to Ministry of Food and Agriculture (MoFA) statistics for 1994, the areas in Brong Ahafo region alone under vegetable cultivation were over 67,000 hectares with tomatoes accounting for 43,500 ha (MOFA, 1994). There is intensification of production and it is common for tomato to be grown continuously on the same land for 15 or more years (Critchley, 1997). This practice has also unwittingly led to the development of various intractable and costly pest and disease problems (Critchley, 1997). The prevailing tropical conditions and the practice of monoculture generally favour the rapid build up of pests (King and Saunders, 1984; Kumar, 1986; Lim and Di, 1990). At high insect infestation, no marketable produce is harvested if insecticides are not applied to control them (Kay, 1989). The benefits therefore impacted on vegetable production by pesticide usage are very high as these chemicals increase the yield through the control of noxious crop pests.

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Brempong-Yeboah (1992), NARP (1993; 1997), Ninsin (1997) and Critchley (1997) reported in separate studies that vegetable growers in Ghana used unnecessarily large quantities of different classes of insecticides. The number of pesticides is likely to increase in the future because of the high demand for good quality agricultural products and the urgent need for self-sufficiency in food production.

Although consumer awareness and legislation on pesticide residue in food are lacking, pesticide management specialists and scientists are very much concerned about the mis-use of persistent pesticides on vegetables in contrast to long term alternate control measures which advocate the minimal use of selective and less persistent pesticide compounds in the context of Integrated Pest Management. Crops harvested shortly after pesticide application are likely to be contaminated with pesticides that are toxic to humans. The pesticide residues, which consist of remnants of a pesticide or its toxic metabolites in/on a crop after its use for pest control purposes, may either cause acute or chronic toxicity in humans after the consumption of the treated crop (Borge *et al.*, 1972, Gram and Hansen, 1972, Ripley and Simpson, 1977). The toxic effects of pesticides in vegetables are more apparent when they are consumed fresh (**ICAR** Extension Folder: 59).

It is for these reasons and general food safety that, the Food and Agriculture Organization (FAO) and World Health Organization (WHO) of the United Nations (UN) have since 1961 set Maximum Residue Limits (MRL's) of pesticides in foods produced from the use of pesticides according to Good Agricultural Practices (GAP) (Oudedjan, 1994). There is therefore the pressing need for monitoring pesticide usage and contamination in food commodities to provide useful information on assessing the safety to consumers of treated food products in the local market and for export.

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The prospects of enhancing the farmers' role, as an independent decision-maker on safe and efficient use of pesticides in the context of IPM requires a realistic assessment of crop protection practices on farm with particular reference to pesticide use patterns. Baseline information needs to be obtained to appreciate farmers' knowledge and practices and to assess opportunities as well as constraints for decision-making at the farmer level for sustainable pest management practices in tomato production.

1.1 Specific objectives

The specific objectives of the study were;

a) To assess farmers' knowledge and perceptions of insect pest problems with the view of providing appropriate suggestions for rational and feasible pest control strategy in tomato production.

b) To review tomato cropping systems in two selected production areas of Ghana.

c) To review farmers' pesticide use pattern in two selected tomato production systems in Ghana.

d) To identify and determine residue levels of Lindane, Endosulfan and Chlorpyrifos insecticides in tomato and compare with the FAO/WHO MRL's

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CHAPTER 2

2.0 REVIEW OF LITERATURE

2.1 Origin, distribution and importance of tomato

Tomato *Lycopersicum esculentum* Mill originated from tropical Central and South America (Equador and Peru) (Purseglove, 1966). The crop was introduced into Europe in the early sixteenth century and spread to the Phillipines via South Africa and to Malaysia (Purseglove, 1966; Tindal, 1986; Hill and Walter, 1994). Today, tomato is one of the most popular and widely cultivated vegetables in the world especially in the warm, temperate and cooler tropical regions with over 35 metric tons produced annually (Tweneboah, 1998).

Tomato was possibly brought to West Africa by the Europeans around 1870 or across the continent from Egypt or the Sudan (Tindal, 1986; Sinnadurai, 1992). Tomato forms an important component in the diet of West Africans and is eaten in large amounts. The fruits are eaten raw or cooked. Large quantities of tomato are used in the preparation of soup, juices, ketchup, puree, paste and powder. It has a high nutritional value and contains vitamins A and C (Appendix A). Tomato seeds contain about 24% oil and this is extracted for use as salad oil and in the manufacture of margarine. Although tomatoes generally rank low in comparative nutritional value, they outrank all other vegetables in total contribution to human nutrition because so much is consumed in so many different ways.

2.2 Major production areas of tomato in Ghana

Tomato is widely produced in Ghana (Table1). According to Tweneboah (1998), the following areas are recognised for tomato production on commercial scale in Ghana;

(a) A belt extending from Ashaiman/Dawenhya to Sege and Ada in the Greater Accra Region.

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(b) The Mankesim/Agona Swedru and Nsawam areas in the Central and Eastern Regions.

(c) The Ohawu-Keta areas in the Volta Region.

(d) The Wenchi-Kintampo areas, Derma and Tano district in the Brong-Ahafo Region.

(e) Offinso (Akomadan) and Mampong areas in the Ashanti Region.

(f) The Tono and Vea Irrigation project areas and Pwalugu in the Upper East Region.

Table 1. Tomato Production in Ghana (1995)

Region	Area Ha	Yield T/ha	T	Value Cedis`000,000
Western	1,090	9.2	10,000	3,000
Central	2,140	8.2	17,500	5,280
Eastern	1,220	9.8	12,000	2,840
Greater Accra	1,380	8.1	11,200	3,390
Volta	1,090	15.6	17,000	5,100
Ashanti	2,930	15.2	44,500	13,440
Brong Ahafo	2,900	16.0	46,400	13,920
Northern	770	13.4	13,300	3,210
Upper East	2,500	16.6	41,500	12,480
Upper West	100	8.0	800	400
TOTAL	**16,120**	**13.2**	**212,800**	**63,900**

Source: Based on PPMED Statistics (Nurah, 1999)

2.3 Major insect pests of tomato

Several insect species are associated with tomato but those of economic importance belong to four major orders namely; Diptera, Hemiptera, Lepidoptera and Orthoptera (Forsyth, 1966;

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Froshlich and Rodewald, 1970; Critchley, 1997) (Table 2). By far the largest number of species occurs in the order Lepidoptera. Critchley (1997) reported that up to 29 species of noctuid moths are associated with tomato in Ghana but only a few are important.

The most serious economic pests are:

(i) White fly, *Bemisia tabaci* Genn (Hemiptera: Aleyrodidae).

This is a serious pest attacking tomato plants. Adults and the sessile nymphs feed on the undersurface of leaves and secrete sticky honeydew on which sooty moulds can develop. During feeding it transmits the Tomato Yellow Leaf Curl Virus (TYLCV), which seriously affect the productivity of tomato plants (Hill and Walter, 1994). Originally, the white fly was a minor pest in Ghana but now a major pest due to widespread use of pesticides, which have destroyed the ecological balance by killing its natural enemies (Critichley, 1997). It is an important vector of virus diseases affecting tomato, cassava, cotton, tobacco, and sweet potato. Leaves of affected plants are distorted, reduced in size or twisted. Chlorosis of the leaves affects photosynthesis and leads to reduced yields.

(ii) Cotton bollworm (tomato fruit borer) *Helicoverpa (Heliothis) armigera* Hubner (Lepidoptera: Noctuidae).

This is a polyphagous moth, which attacks a wide range of plants including cotton, tobacco, tomato and other vegetables, legumes and many wild fruits. It is very widespread and sporadically very serious pest of cotton and beans in many parts of the world. The larva prefers to attack the reproductive parts of the plant including buds, flowers and green unripened fruits causing the fruits to rot and drop. They also feed on leaves.

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Table 2. Major insect pests of tomato in Ghana

Names of Pests	Order	Damage
White flies *Bemisia tabaci* Gennadius	Hemiptera	Feed on leaves. Transmits viruses
Cotton bollworm *Helicoverpa armigera* (Hubner)	Lepidoptera	Bores into fruits, feed on leaves and flower buds.
Cotton leafworm *Spodoptera litorallis* (Boisd.)	Lepidoptera	Feeds on leaves, bore into buds and green unripe fruits
African mole cricket *Gryllotalpa africana*	Orthoptera	Cut off transplanted seedlings
Leafminer flies *Liriomyza spp*	Diptera	Larva mines leaves
Variegated (elegant) grasshopper *Zonocerus variegatus* (L.)	Orthoptera	Feeds on stems and leaves.
Cotton aphid *Aphis gosspii* Glover	Hemiptera	Attacks terminal shoots and under surface of leaves
Cutworm *Agrotis ipsilon*	Lepidoptera	Cut stems below soil surface
Fruit piercing moth *Achae lienardi* (Boisd)	Lepidoptera	Attack fruits by piercing.
Cotton semi-looper *Anomis flava* (*Cosmophila flava)* F.	Lepidoptera	Larvae feed on leaves whilst adults attack fruits
Green (shield) bug *Nezera viridula* (L.)	Hemiptera	Adults feed on leaves and suck sap.
Plant bugs, *Nesidiocoris tenuis* Reuter	Hemiptera	Feed on truss and flowers
Endocrima fullonia (Clerck)	Lepidoptera	Adults feed on fruits to cause rot

Source: Forsyth (1966); Critchley (1997).

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Owing to overuse or misuse of pesticides, this moth is now resistant to most insecticides in many parts of the world (Vassal *et al.*, 1997; Ahmad, 1997).

(iii) Cotton leafworm *Spodoptera littoralis* (Boisd) (Lepidoptera: Noctuidae).

It is a polyphagous pest attacking cotton, rice, maize, tobacco, tomatoes, castor, citrus, mulberry, cruciferae, legumes, many other vegetables and ornamentals. They are widely distributed throughout the warmer parts from Africa to the Far East and Australia. The caterpillars feed principally on the leaves and heavy infestation results in serious defoliation. They also bore into buds and green unripe fruits which later rot and drop.

(iv) African mole cricket *Gryllotalpa africana* (Orthoptera: Gryllotalpidae).

This pest attacks seedlings of several herbaceous crops and is sporadically a serious pest especially in humid climates with moist soils at lower altitudes. The first instar nymphs remain in the nest and are fed by the mother. Later instars rest in the burrow during the day and forage on the soil surface at night. Roots are eaten below the soil surface. Transplanted seedlings and young plants are cut off completely.

(v) Leafminer flies *Liriomyza spp* (Diptera: Agromysidae).

These flies are small and usually black or yellow in colour. The larvae, which are white maggots, are leafminers, and the adults occur almost everywhere and are very polyphagous. Among the crops they attack are cowpea, garden egg, okra and tomato. Most species are more easily recognized by their mines than by the insects themselves. The larvae make serpentine mines in the leaves. The mines are narrow initially and increase in width as the larva grows, reducing the photosynthetic area of the leaf. In severe infestations, the leaves dry up and there is a risk of flower bud and fruit scorching, resulting in reduced yields. Chemical control of leaf miners is difficult because the larvae are well protected from contact insecticides. Such control measures are best avoided as repeated insecticide applications can

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provoke high populations and outbreaks resulting in defoliation and severe yield losses (Spencer, 1973).

(vi) Variegated (elegant) grasshopper, *Zonocerus variegatus* (L) (Orthoptera: Acrididae), Pyrgomorphidae

It is a major polyphagous defoliator of a wide range of plants especially at the seedling stage including cassava, millet, cocoa, castor, cashew, coffee, cotton, sweet potato, oil palm, citrus and many vegetables. As they feed on young plants, they cause extensive defoliation and leave characteristically ragged edges. They also feed on the stems by stripping the back. It is a sporadically severe pest of many crops in many parts of Africa particularly during dry spells of weather and early rains.

(vii) Cotton aphid *Aphis gossypii* Glover (Hemiptera, Homoptera: Aphidae).

Aphids are amongst the world's most damaging pests. Adults and nymphs attack mainly the terminal shoots and, like white flies, feed on the underside of leaves and are nuisance when they facilitate the development of sooty moulds on the fruit and foliage, (Hill and Walter, 1994).

(viii) Cutworm, *Agrotis ipsilon* Hufn (Lepidoptera: Noctuidae)

A. ipsilon is a highly polyphagous insect attacking many species of host plants in the temperate, subtropical and tropical zones. Host plants include potato, tomato, onion and pepper. Mature larvae cause the main damage. These live in the soil near the food plants and first cut the stem below the soil surface, leave it and then attack another plant. The injured plants wilt and the insect can wither a number of seedlings in this manner in a single night. The young larvae feed on the leaves of many crops.

(ix) Fruit piercing moths, *Achae lienardi* (Boisd.), (Lepidoptera: Noctuidae).

These may cause damage to fruits (Forsyth 1966; Holloway *et al.*, 1987). *A. lienardi* adults rather than the larvae cause the main damage, as they use their stout spiny proboscis to pierce

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ripening fruits and suck sap. They are particularly abundant during the early rains. Being nocturnal in habit, they are not easy to control with insecticides especially as the larvae do not feed on the same crop.

(x) Cotton semi-looper *Anomis* (Cosmophila) *flava* Fab. (Lepidoptera: Noctuidae) The larvae are semi-loopers, which feed on the leaves and can cause severe defoliation. Adult moths can also cause damage to the fruit by means of their satcheted proboscis. This noctuid is a minor pest of tomato.

(xi) Green (shield) bug *Nezera viridura* (Hemiptera, Heteroptera: Pentatomidae). The adults and nymphs suck sap from the foliage. Adults do feed on green fruits. The pinpricks they cause with their feeding stylets result in small dark circular patches surrounded by a light ring, which remains yellow or green on ripe fruit.

(xii) Plant bug *Nesidiocoris tenuis* (Hemiptera, Heteroptera: Miridae). The adults and nymphs feed on the leaf petioles and stems of young plants. Damage is caused in three ways: by the piercing and sucking of plant sap, by the injection of toxic saliva and during egg laying by the female insects.

(xiii) *Endocima fullonia* (Clerck) (Lepidoptera: Noctuidae). The adults have modified proboscis for piercing fruit. In doing so, they introduce fungi that cause the fruit to rot and drop prematurely. It is difficult to control because of its wide host range and the fact that the adult moths feed only temporary on the fruit and are active mostly at night (Critchley, 1997).

2.4. Major diseases of tomato in Ghana

According to Critchley (1997), at least 16 diseases of tomato are recorded in Ghana. They are caused by two bacterial pathogens, 13 fungal pathogens and at least two viral pathogens, the latter being more prominent in the forest zone. Some of these major diseases are described in Table 3.

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Table 3. Major diseases of tomato in Ghana.

No.	Disease type	Symptoms
i	Damping off	Seedlings in nursery wilt and fall over
ii	Bacterial wilt	Plants wilt suddenly or during warm days.
iii	Early blight	Leaves have black or brown, round spots.
iv	Late blight	Leaves have black or brown irregular shaped, spots or dead areas.
v	Tomato Mosaic Virus (TMV)	Leaves are crinkled and curled.
vi	Fusarium wilt	Leaves especially older leaves turn yellow.
vii	Root knot nematode	Plants roots have galls.

(Source: PANS, 1983 & Critchley, 1997)

2.5 Chemical control and pesticide use in Ghana

Traditionally in Ghana's Agriculture, pesticides have been used primarily for the control of pests of export crops, such as Cocoa, Coffee and Cotton (NARP, 1993). Currently, pesticide use has assumed an increasingly significant role in the production of food crops such as cowpea, rice and vegetables with limited usage on maize, cassava and the prevention of vector borne diseases (NARP, 1993; Dixon, 1995).

The widespread use of pesticides is partly due to the advantages they offer. They can be reliably effective in preventing loss of yield and thus reduce the financial risks of such losses. Most pesticides are quick in activity and can be used for immediate control of pest outbreaks. These advantages have led to the use of pesticides as a crucial tool for effective protection in

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agriculture and therefore seen as an essential component of integrated control (Oudejans, 1994).

In Ghana, annual imports of pesticides for the Cocoa industry alone increased from 270 tons in 1970 to 2,250 tons in 1981- 82 (Dixon, 1995). According to Bull (1982), in 1980, Ghana was the second biggest West Africa importer of pesticides from the United Kingdom (one of the world's biggest exporter of pesticides). After 1980, with the launching of the Economic Recovery Programme, the use of other pesticides including herbicides, fungicides, rodenticides, growth regulators and others increased drastically. By mid 1980's large quantities of extremely hazardous pesticides of all kinds were being used to control agricultural pests and diseases (Table 4).

From the National Plant Protection and Pesticide Regulatory Committee Report to National Agricultural Research Project (NARP, 1993), the removal of government subsidies on pesticides led to an increase in their cost and subsequent reduction in their use.

Table 4. Volume of pesticide usage within the past 40 years (1951 – 1991) in Ghana.

Pesticide Group	1951-1960	1961-1970	1971-1980	1981-1990	1991
Insecticides	100,000 litres	270,000 litres	500,000 litres	1,903,000 litres	421,600 litres
Herbicides	-	-	5,720 litres	360,000 litres	115,000 litres
Fungicide	-	-	5,000 kg.	150,000 kg.	20,000 kg
Others			1,000 kg	10,000 kg.	260,000 kg

(Source: NARP 1993; Dixon 1995)

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However, in line with government policy of privatization, the pesticide market has been liberalized, and this has recently led to an increase in the total quantity of pesticides imported by the private sector. The latter accounts for about 74% of total imports of pesticides by sector from 1995 – 1998 (Gerken *et al.*, 2000) (Table 5). This policy has paved way for strong preference for cheap pesticide products in the Ghanaian market for the control of pests of field crops.

Table 5. Official pesticide imports by sector (MT) 1995 – 1998

Sector	Year (%MT) 1995		1996		1997		1998	
Public								
♦ COCOBOD	213	48	616	66	1,248	69	125	19
♦ MOFA	34	8	47	5	62	3	47	7
Private	191	44	273	29	516	28	490	74

(Source: Gerken *et al.*, 2000)

Between 1995-1998, different types of pesticides were allowed in the Ghanaian market without an effective mechanism for monitoring their use. For example, 29 insecticides, 18 herbicides, 10 fungicides and four nematicides in different formulations and trade names belonging to about 30 pesticide families have been officially allowed on the market during this period (Gerken *et al.*, 2000).

From the total pesticides imports from 1995 – 1998, insecticides cover about 68.8%, fungicides (16.0%), herbicides (12.6%) and nematicides (2.4%) (Gerken, e*t al*; 2000) (Table 6). These products range from class 1A (extremely hazardous) to class III (slightly hazardous) according to toxicity levels of classification (WHO, 1986) (Table 6).

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measures. These preconditions are generally not followed in many developing countries including Ghana. Thus, they pose a major danger to life and the natural environment. According to WHO (1992), in no circumstance should "restricted" pesticides, which are usually identified or marked with the skull and cross bone sign, be made available for use by the small – scale or untrained farmer, or by the general public.

Table 6: Official pesticide imports for 1995 – 1998 (in metric tonnes)

Type	Year				Average	% of total
	1995	1996	1997	1998		
Insecticides	194	670	1519	349	683	68.8
Herbicides	89	55	132	225	125	12.6
Fungicides	134	192	130	183	159	16.0
Nematicides	21	22	51	5	24	2.4
Total	436	939	1,824	761	993	100

(Source: Gerken *et al.*, 2000)

Currently, 10 pesticides have been banned in Ghana (Table 9). The reasons for their ban are either the persistence of the pesticide in the environment or high toxicity. This is in line with international conventions. Eight more pesticides have restricted application (Table 8). Among this group are Unden and Lindane insecticides, which are registered for capsid control in cocoa.

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Table 7: Quantity of imported pesticides by WHO Class for 1995 - 1998

	Hazardous Class	Qty (MT)	Percentage %
1A	Extremely Hazardous	32	0.8
1B	Highly Hazardous	374	9.4
II	Moderately Hazardous	2,572	64.7
III	Slightly Hazardous	750	18.9
IV	Unlikely Hazardous	243	6.2
Total		**3,972**	**100.00**

(Source: Gerken *et al.*, 2000)

Table 8: Provisional list of severely restricted pesticides in Ghana.

Name	Active ingredient
Azodrin	Monocrotophos
Unden	Propoxur
Lindane	Gamma BHC
Elocron	Dioxacarb
Gramaxone	Paraquat
Furadan	Carbofuran
Thiodan	Endosulfan
Atrazine	Atrazine

Source: Environmental Protection Agency (EPA): Draft for Legal Instrument of Act 528, Accra.

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Table 9: Provisional list of banned pesticides in Ghana.

Name	Active Ingredient	Reason for ban
Aldrex T	Aldrin and Parathion	Persistent, highly toxic
Aldrin	Aldrin	Persistent
Dieldrin	Dieldrin	Persistent
F-605 Combi	Parathion	Highly toxic
Parathion methyl	Parathion methyl	Highly toxic
Heptachlor C 10	Heptachlor	Highly toxic
DDT	Dichor – Diphenyl –Trichlor – Ethane	Safer alternatives
EDIB	Ethylene Dibromide	Highly toxic
D-D	Dichlorpropane	Banned internationally
Bidrin	Dictophos	Banned internationally

Source: Environmental Protection Agency (EPA): Draft for Legal Instrument of Act 528, Accra.

In Ghana, commercial vegetable growers use insecticides to protect their crops from the attack by insect pests. Not only are the dosages applied very high, but also, the spraying intervals are short (Brempong-Yeboah, 1992; NARP, 1993, 1997; Ninson, 1997).

In two farmers surveys conducted during the dry and rainy season in the Brong Ahafo Region, Critchley, (1997) observed that among fairly large–scale commercial producers, pesticide usage had resulted in yields that were several times greater than would be possible

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pesticide usage had resulted in yields that were several times greater than would be possible without them, so that their continued use is now obligatory. However, the way the pesticides were being applied and the reasons for their use left much to be desired. For instance, few or no safety precautions were being taken when mixing or spraying insecticides and rarely were chemicals targeted against specific pests.

A study on pesticide management and contamination at Akomadan, a major tomato-growing centre in the Ashanti Region of Ghana revealed that farmers use about 27 different pesticides against insect pests and diseases attacking tomato. Insecticides mostly used were Pyrethroids (70%), Organophosphates (19%), Carbamates (7%) and Organochlorine (4%) (Ntow, in press). In view of the continuous use of pesticides in the production of tomato in the region, it is expected that an appreciable build up of residues will occur with time.

Some case studies in the southern and middle belts of Ghana (Clarke *et al.,* 1997; Yeboah 1998) have revealed that about 70% of the illiterate farmers in the Eastern and Greater Accra Regions received instructions on how to use pesticides from pesticide dealers. About 47% of the literates read instructions on the label while 31% depended on their own discretion. Recommended procedures regarding storage, mixing or application of pesticides were not followed.

In more recent years, research activities are focussing on the use of botanicals particularly neem to control pests of vegetables and other horticultural crops, because of their rapid biodegradability after application and relative safety to the environment. Components of the neem seed and leaves contain the triterpenoid Azadirachtin (Schmutterer *et al.*, 1982; Schmutterer and Ascher, 1987) that is active against a great number of insect species. This led to a growing interest and to the hope that vegetable farmers will frequently use natural insecticides from the neem tree in the future. However, farmer surveys to evaluate the extent of knowledge and use of neem products in Ghana conducted in the Forest Zone, Coastal

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Savannah and Interior Savannah in 1998 revealed that 80% of farmers interviewed used neem for one or more purposes. Of these, 73% reported that they use neem for medicinal purpose, 17% for fuel wood, and 14% and 9% for protection of field crops and stored products, respectively (Manu *et al.,* 1999). In the same survey, 67% of farmers used synthetic pesticides for crop protection. Synthetic pesticides were mostly used on vegetables such as cabbage, tomato and eggplant.

The use of neem to protect field crops was directly linked to the IPM project at Weija. Elsewhere in Ghana, very few farmers used neem for crop protection (Childs, 1999). The most cited constraint to the use of neem for crop protection in Ghana was the fact that preparations were time consuming and labour intensive (Manu *et al.,* 1999).

2.6 Problems arising from pesticide over-use

2.6.1 Development of pest resistance to pesticides.

A common and serious problem arising from indiscriminate and excessive use of pesticides is the development of pest resistance in various organisms in a relatively short period of time (Table 10). Although pest resistance has not been quantified by bioassays for most of the vegetable pests, it has been confirmed for a few, and thoroughly examined in the Diamond-backmoth (DBM) *Plutella xylostella* (L.) where the problem is especially acute (FAO, 1990). Resistance of the DBM to convectional insecticides and *Bacillus thuringiensis* subsp. Kurstaki Berliner is documented globally (Tabashnik *et al.*, 1990; Perez and Shelton, 1997).

The considerable selection pressure which *H. armigera* has experienced, particularly to the synthetic pyrethroids has also resulted in the development of resistance to the major classes of insecticides in many of the areas where these have been used (Vassal *et al.*, 1997). Field failures resulting from pyrethroid resistance have been reported from Australia, Thailand, Turkey, India, Indonesia and Pakistan (Armad, 1997; Vassal *et al.*, 1997).

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This pest costs the Australian agriculture sector about $225 million per year in its management and lost production (Adamson *et al.*, 1997; Davis *et al.*, 1997). This cost is rising as the insects become more resistant to insecticides and the area of susceptible crops increases. This situation is likely to be the same in most tropical regions.

Table 10: Number of species of insects and mites resistant to (a) DDt and methoxychlor, b) HCH, lindane cyclodiences, texaphene, (c) organophosphates, (d) carbamates and (e) synthetic pyrethroids.

Year	Total	a	b	c	d	e
1938	7	7	0	0	0	0
1948	14	13	1	0	0	0
1954	25	22	18	3	0	0
1969	224	155	42	23	4	0
1979	364	221	70	44	22	7
1980	428	245	95	53	25	10
1984	447	234	119	54	23	7
1989	504	263	291	260	85	48

Source: Georghiou and Lagunes-Tejeda, (1991).

The recent trend has been to increase dosages or change to other products to increase effectiveness. There was a shift from the early botanicals to the organochlorines, then to organophosphates, carbamates, and pyrethroids and then to the use of insect growth regulators (IGRs), (Lim, 1988). Of special interest are the IGR's which, although only recently introduced to Asia, have rapidly begun to lose their effectiveness. In both Malaysia

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and Thailand, resistance development has already been detected (FAO, 1990). In Malaysia, 3 teflubenzuron and triflumuron showed resistant factor (rf) values of 12-16 and 16-18, respectively (Lim *et al.*, 1988). Diflubenzuron, the oldest of these IGRs, is now almost completely ignored by farmers because of its low effectiveness (Lim, 1988).

In Ghana, carboxylesterase analysis of *P. xylostella* population collected around Accra indicated the probable incidence of insecticide resistance in the insect population (Kaiwa, 2000). Collections in 1995, 1996, 2000 and 2001 on vegetables have indicated the presence of insecticide resistance genes in population of aphids (Owusu, Personal Communication). Most of aphid populations studied over the period were classified as moderately resistant or resistant. Many new cases of resistance development of pests of vegetables are certain to be reported as researchers begin to explore a wider range of associated pest or organisms.

2.6.2. Health effects of agrochemicals

Excessive use of pesticides without protective measures or regard for safety from contamination has given rise to increasing cases of health effects to humans. The two main types are chronic effects and acute effects.

2.6.2.1 Chronic toxicity

Chronic poisoning follows repeated or long-term exposure or absorption of small amounts of toxicant. Contact dermatitis resulting from long-term exposure to pesticides is also a fairly common problem among vegetable farmers. However, it is usually not critical as the symptoms normally disappear when the farmers stop using the pesticides. As such, contact dermatitis is not widely publicized and affected persons are effectively treated with a cortisteroid cream.

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The following are certain chronic toxicity properties of some insecticides compiled by Extension Toxicology Network (EXTOXNET) (1993, 1995) and Yousefi (1999):

Dimethoate : - Dimethoate is possibly a human teratogen. It is also a mutagen and carcinogen. Dimethoate may also cause organ toxicity. The testicles of male rats exposed to dimethoate decreased in size. These rats also developed chronic kidney problems.

Cypermethrin : - Cypermethrin is a possible human carcinogen. Long term exposure to cypermethrin may also cause liver changes. Pathological changes in the cortex of the thymus, liver, adrenal glands, lungs and skin were observed in rabbits repeatedly fed with cypermethrin.

Methyl Bromide : - damage to the lining of the lungs causing the lungs to fill up with fluid and the victim to collapse with respiratory failure.

Paraquat : - causes irreversible thickening of the lungs. Pulmonary function is impaired, with the lungs being unable to absorb sufficient oxygen.

Dibromochloropropane : shown to cause sterility and only partially reversible after withdrawal from exposure in men.

2.6.2.2 Acute toxicity

Acute toxicity is the immediate poisoning resulting from a single exposure or intake of a toxicant (Oudejans, 1994; Yousefi, 1999). Many agrochemicals act on insects, by damaging the nervous system. In the same way, these chemicals (e.g. organophosphates) may be harmful to human nerves, either affecting the nervous tissue in the brain or the nerves controlling breathing (Yousefi, 1999). Most fatal poisonings are caused by organophosphate pesticides such as Dursban, Gusathion, Azodrin, Lebaycide and Rogor (Yousefi, 1999).

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Many others including the organochlorine pesticides such as DDT and Dieldrin can also cause nervous system damage.

In Ghana, a study conducted by Clarke *et al.*, (1997), to examine the extent of pesticide associated symptoms in farmers involved in irrigation projects in Ghana, revealed that about 36% of interviewed farmers had experienced negative side effects after applying pesticides. The most significant symptoms included headaches, dizziness, fever, blurred vision and nausea/vomiting. Due to a general lack of awareness of the associations between these symptoms and pesticide poisoning, farmers do not seek medical treatment.

In a study of 153 vegetable growers in Malaysia, 28.1 percent of them had experienced various forms of poisoning symptoms (Ramasamy and Nursiah, 1988). These include complaints of headache, dizziness, general fatigue and skin rashes soon after a pesticide spraying operation. Follow-up observations revealed that these symptoms were caused by pesticide inhalation or sustained exposure and dermal contact with chemicals, especially organophosphates.

In Ghana, a true assessment of health hazards related to pesticide use in agricultural production raises difficulties because there is hardly any authoritative statistics available on poisoning from pesticides. Cases of pesticide poisonings are therefore under-reported. Some few reported cases of fatal pesticides poisoning in Ghana are presented in Table 11. The most recent reported incidence in the country occurred in Pwalugu, a tomato growing area in Upper East Region where two farm hands died instantly after eating fresh tomato fruits sprayed with organophosphorus insecticide during the 1999/2000 irrigated dry season (Personal Communication).

According to Ministry of Health (1999) report, there was an instance of poisoning when three children died of possible overdose of carbamate in fruits in March 1999. Medical investigation after the incident supported the hypothesis of wrong application of carbamates.

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In both situations, the farmers probably did not observe the necessary waiting period between the last application and harvesting. There are other unofficial reports of pesticide poisoning cases throughout the country including suicide - attempted cases.

Table 11: Some fatal pesticide poisoning cases reported in Ghana (1986-1996)

Year	Number of Reported Cases	Remarks
1986	4	All staff of PPRS
1987	9	All volunteers, one died at Navrongo in the Upper East Region during the army worm control
1988	6	All farmers, one died in the Volta Region during control of army worms
1989	4	Staff of PPRS. Others were farmers.
1992	8	All farmers' children died after eating mango fruits contaminated with seed dressers.
1996	5	All household members died in Volta Region after eating okro sprayed with insecticide.

Sources: FAO, (1989), Dixon, (1995) and Atsu, (1996)

In 1972, the World Health Organization (WHO) Expert Committee on the safe use of pesticides published accidental poisoning statistics for 19 countries. The report stated that there were as many as 500,000 cases worldwide of pesticide poisoning occurring annually. Of the resulting 900 or more deaths, a startling 99% were in the Third World.

In 1977, based on notification from several governments and official surveys held in nine countries, WHO estimated that the number of deaths globally has risen to about 20,640 per year. In 1981 OXFAM updated the WHO figures, and estimated that the world's pesticide – related poisonings total around 750,000 per year. More recently, the Economic and Social

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Commission of Asia and the Pacific (ESCAP) suggested that pesticide-poisoning accidents might have risen to two million yearly, of which 40,000 could be fatal.

Specific studies carried out in Asia and reported by FAO (1990), revealed the following;

In the Philippines for example, 97 cases of pesticide poisoning with 14 deaths were reported between 1980-82 by Benguet General Hospital in the Mountain Province, a major vegetable-growing area (Castaneda, 1988). The Ministry of Health in Philippines, recorded a total of 238 cases in 1982, 563 in 1983 - 84 and 79 in 1985. Of these, 63.3% were suicide, 17.8% occupational poisoning, 16.5% accidental, and the remaining cases due to unknown reasons. The types of pesticides involved included 42% of organophosphates, 19% organochlorines and 14 percent carbamates.

The situation in Thailand is perhaps slightly more serious. In 1985 alone there were 4, 046 cases of pesticide poisoning mostly of farmers from 55 provinces, with 289 deaths (Kritalugsana, 1988).

2.6.3. Hazards to non-target organisms.

Hazards to non-target organisms from over-use of pesticides in vegetables are not well known. However, it has been observed that birds were common victims when isobenzan was used extensively against DBM in Malaysia between 1964 and 1966 (FAO, 1990).

In Thailand, studies by Tayaputch and Mahittickurin (1980), revealed the presence of pesticide residues in the stomach contents, livers and tissues of 90 species of birds in the agricultural central plain area. Included were traces of 14 organochlorines among which DDT, Aldrin and Dieldrin were most common. The levels were mostly less than 18ppm and not considered harmful (Bernard, 1966).

There are vast number of natural parasites and predators of crop pests, which maintain a natural balance of biodiversity at the farm level. Concerning arthropods, the deleterious

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effects of pesticides are strongly indicated by the drastic decline in the insect fauna on treated crops. Not unexpectedly, any beneficial species (particularly arthropod parasitoids and predators) that may have existed are also likely to be decimated. This has been proved experimentally for the DBM parasitoid, *Apanteles plutellae,* using the chemical exclusion method (Lim, *et al.,* 1986).

In Ghana, a good example of this interference was observed in the Brong Ahafo Region in 1991, when fenitrothion insecticide was sprayed to control grasshopper *Zonocerus variegatus* (L). The insecticide simultaneously killed the parasitoid *Epidinocarsis lopezi* (DeSantis) that has been introduced intentionally as a biological control agent to control the cassava mealybug *Phenacoccus manihoti* Matile-Ferrero (Herren and Neuenschwander, 1991; Dixon 1995).

According to Critchley (1997), the whitefly *Bemisia tabaci* Gennadius is not listed in any Ghanaian publication prior to 1990 as a pest of vegetables and yet it is now probably, the most serious pest. This is a classic `man-made' pest, which has developed as a result of the destruction of its natural enemies from the overuse or misuse of pesticides or probably due to resistance build-up.

2.6.4 Rise in production cost.

Another major problem usually encountered is the rise in production costs associated with increased use of pesticides. For example, insecticides alone contribute about 30% of the costs in cabbage cultivation in Malaysia (Lim, 1972).

Studies in the Brong Ahafo on the economics of tomato production indicated that pesticide cost alone constitutes about 35% of the total production (Wolff, 1999). The spiralling cost is also largely necessitated by the development of pesticide resistance, which gives rise to the need for higher dosages and more frequent applications. The resultant effects of increased

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concentrations of insecticides for pest control are the problems of increased financial investment in pesticide purchase and phytotoxicity (Sances *et al.,* 1981; Toscano *et al.*, 1982).

2.6.5 Pesticide residue in food crops.

The repeated and indiscriminate use of pesticides in crop protection have created the problem of human health hazard due to their toxic residues that persist in food after their application. The small concentrations of these toxic residues may have substantial biological consequences (Kumar, 1986). The most likely sources of residues may arise from over application of pesticides or use of very high doses as a result of resistance build up and/or the use of restricted organochlorines, which are highly persistent.

In Ghana, few studies have been carried out on monitoring of residue levels of foodstuff particularly vegetables. Ninson (1997), using bioassay method with the Brine Shrimp, *Artenia selina*, leach as a test organism, revealed that about 33% of the cabbage samples bioassayed showed residue levels likely to be 6 fold higher than the FAO/WHO MRL for Triazophos insecticide. The inadequacies and limitations of the method employed made him to recommend further analytical methods in future for residue analysis on assorted vegetable crops so as to be able to identify the parent pesticide compounds and their metabolites, and also establish precise amounts of residues levels.

Studies on pesticide management and contamination at Akomadan, a major tomato growing area in the Ashanti Region of Ghana, indicated HCB concentrations ranging from 0.07 - 0.30 ng /g in water bed sediment, and 0.16 - 3.13 ng/g in tomato food crops and leaves (Ntow 2001). On the average, the residue levels were low and below FAO/WHO MRL.

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2.7 Pesticide residue violations.

In Ghana, no comprehensive information covering vegetable and other food crops on their residue status and national tolerance limits is available. Elsewhere, frequent cases of pesticide residue violations in countries that have legislations that set MRL's and ADIs for pesticide residues in food have been reported.

Foodstuffs collected from different regions in India were analysed for the presence of HCH (BHC), DDT, HCB, Aldrin, Dieldrin, Heptachlor and PCBs. Significantly high levels of food contamination with HCH, DDT, Aldrin and Dieldrin were evident throughout India (Kannan *et al.,* 1992).

In the ICAR Extension Folder 58 and 59, monitoring of pesticide residues in India also showed that 40% - 60% samples were contaminated with pesticide residues. In most cases the residues exceeded the MRL's and most chemicals found were the highly toxic and persistent chemicals like DDT and BHC. There were however, variations in the level of contamination in different vegetables; 48% cabbage; 51.1% tomato; 74% chilli; 45.6% potato; 51.7% brinjal; 61.8% cauliflower, 58% okra 78.1% bean; 33.3% onion; 93.3% gourds; and 96.4% leafy vegetables samples were found contaminated across the country.

In Malaysia, significant levels of residues on tomatoes were confirmed in the early 1980's through chemical assays (Lim, *et al.,* 1983). Tomatoes obtained from several local markets had residues of dithiocarbamates fungicides ranging from 0.21 mg/kg to 15.8 mg./kg CS2. At least four out of six samples analyzed were found to contain residues in excess of the maximum residues limit of 3 mg/kg check set by FAO/WHO (1978). Most residues were concentrated in the peels, of which 50 – 86% could be removed through washing (Lim *et al.,* 1983).

The presence of high residues on *Brassica rapa* is also of concern (Lim *et al.,* 1983). It was noted that at higher concentrations of applied endosulfan (0.5%) and Permethrin (0.04%), the

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total residues might reach a level of 184.28 ug/g and 10.31ug/g, respectively. For endosulfan, the levels of the alpha, beta and sulphate components were correspondingly 63.12 ug/g, 110.68 ug/g and 10.48 ug/g.

In the Philippines, pesticide residues have been detected in a number of vegetables (Ramos – Ocampo *et al.*, 1988). On Cabbage, detectable residues of mevinphos and triazophos were mainly concentrated on the outer leaves where a considerable amount can be removed by washing and removal of the wrapper leaves (Magallona *et al.*, 1977, 1981).

The concern for pesticide residues in agricultural products has been noted in Thailand. A survey was conducted by the Department of Agriculture from 1972 to 1981 on more than 2,000 samples of produce, including 66 vegetables encompassing cabbage, cauliflower, chineese kale, beans, and green mustard (Tayaputch, 1988). The study revealed that a relatively large number of samples were contaminated with organochlorine residues, especially BHC; heptachlor and its expoxide; aldrin, diedrin, endrin, DDT and metabolites. Organophosphates were mainly dimethoate, ethyl parathion, parathion, methamidophos, mevinphos, monocrotophos, diazinon and dichlorvos. The cabamate residues, however, were largely benomyl and carborfuran.

In 1992 – 1993, the US Food and Drug Administration (FDA) conducted a statiscally based study of pesticide residues in domestic and imported pears and tomatoes. For tomatoes, 1219 domestic and 114 imported samples were collected and analyzed; 84% of the domestic and 114 imported samples had detectable residues. Methamidophos, an organophosphate insecticide, had the greatest frequency of occurrence in both groups of tomatoes. 33 domestic and five imported samples were violative, nearly all resulting from acephate use, for which there is no US tolerance on tomatoes (Roy *et al.*, 1995).

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Elderkin *et al.*, (1995), in his publication "Forbidden Fruit" outlined in respect of vegetable supply in the USA as follows:

"Most people believe that the produce they buy meet pesticide safety standards. But the fruits and vegetables with illegal pesticides end up on grocery shelves, in kitchens, and in lunch boxes throughout the country everyday. Over 90% of the types of violations reported in "Forbidden Fruits" are of two kinds: no-tolerance violations; where the pesticide is found on a crop even though the allowable level for the pesticide on that crop is zero; and over tolerance violations; where the amount of the pesticide found exceeds the legal limit (or tolerance) for that crop. Some major fruits and vegetables have very high rates of illegal pesticides".

In Canada, 13,230 samples of agricultural food commodities were analyzed for pesticide residues in 1993. Results in violation of Canadian tolerances were discerned in 224 samples (Neidert *et al.,* 1994).

Excessive residues on market vegetables pose increasing concern, particularly with respect to general consumer health and the environment, and have generated significant trade implications. For instance in 1987 vegetable exports from Malaysia to Singapore were rejected essentially because of fungicidal residues, although insecticide contamination above acceptable levels was also involved (Lim, 1990).

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2.8 Pesticide residue analysis

The use of pesticides in agriculture result in residues in the crop. The level of this residue in the consumable portion is determined by subjecting food samples to pesticide residue analysis. The multiple residue method (MRM) and single residue method (SRM) are different forms of analytical methods that could be used to determine pesticide residues of different pesticides. Single residue method determines one pesticide. Where the identity of a

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pesticide is not known before analysis, a more general method of analysis may be chosen that allows for the analysis of a wide range of pesticides. Such a procedure is also known as multi-residue method (NRI, 1995).

2.8.1. Sampling for pesticide residue analysis.

When sampling produce for analysis it is important to ensure that:

a) The sample(s) taken for analysis is representative of the larger bulk of produce. In pesticide application, a uniform application of pesticide is difficult to achieve and a range of residues may result. It is important that sampling cater for this variability.

b) Samples are not contaminated in any way during sampling or transportation to the analytical laboratory.

c) Clear and effective labeling is essential for product traceability.

2.8.2. Extraction procedure

Once an analytical sample is in a suitable form, extraction can take place. The process of extraction is to isolate the target contaminants from the sample matrix. The resulting solution consists of pesticide residues and sample co-extractives.

Organic solvents such as acetone, acetonitrile, methanol, dichloromethane or ethyl acetate are widely used as solvent for extraction (NRI, 1995). An ideal solvent system should be highly efficient in the recovery of target pesticide but selective enough not to include excessive interfering co-extractives.

The nature of the sample material may have a major effect on the choice of the extraction solvents. For example, with non - fatty samples of relatively high moisture content, a polar water miscible solvents such as acetonitrle, methanol or acetone is used. A second non polar organic solvent such as hexane, petroleum ether or dichloromethane is then used to

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remove or partition the pesticide residues from the aqueous stage. The solvent extraction involves partitioning using sodium sulphate solution; 5% for high polarity and water soluble residues and 2% for low polarity and water soluble residues. This technique is used for samples such as fruits and vegetables and liquid samples where moisture content can be 90% or greater.

A quicker extraction and partition step by ethyl acetate/ cyclohexane (1+1) is widely used in recent times in multi-residue analysis. When the efficiency of the extraction methods with acetone and with ethyl acetate were compared with regard to the multi-pesticide residue determination in fruits and vegetables, the ethyl acetate method gave higher recoveries for polar pesticides and seems somewhat easier, quicker and cheaper in handling (Anderson and Palsheden, 1991). In general, both methods gave acceptable and equivalent recoveries for the pesticides tested.

2.8.3. Clean – up of sample extracts.

Extraction is followed by clean up which results in the isolation of the target pesticide from interfering co-extractives. The extent of clean – up required prior to final GC determination depends on the sample type and the selectivity of both the extraction procedures and the determination method. The common methods are;

a) Column chromatography used in the analysis of organochlorines and synthetic pyrethroids. It is an absorption chromatography based on the polarity of the analytes. It is primarily used to remove pigments, waxes, polar impurities and small amounts of fats.

b) Gel – permeation chromatography column is commonly used in organophosphorus analysis. Separation is based on the different abilities of the various sample molecules

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to enter pores in the gel. It can be used to separate lipids or other high molecular weight co-extractives from most pesticides.

c) Solid-Phase Extraction (SPE) clean up of organic pesticides using SPE columns fitted with C18 cartridge and florisil, alumina or silica and florisil SPE cartridge are widely used. In this technique, the pesticide of interest is adsorbed into a suitable material packed into a column and eluted from the column by a suitable solvent system. It is widely used because it requires smaller amount of solvents.

2.8.4. Final determination of residues.

The Gas Liquid Chromatograph, which may be fitted with various detectors such as Electron Capture Detector (ECD), Nitrogen Phosphorous Detector (NPD) and Flame Ionization Detector (FID) depending on the type of pesticide/compound being analysed, is often used as the analytical method in residue analysis (GTZ, 1979).

The ECD is extremely sensitive towards halogenated compounds and used for detection of organochlorines and synthetic pyrethroids. The NPD is used for the detection of organophosphorus and N-methyl carbamates (NRI, 1995). The FPD is highly selective detector for sulphur and phosphorus compounds hence require minimum clean - up. It is used for the detection of phosphorus compounds but less sensitive than NPD.

Thin Layer Chromatography (TLC) can be used to screen food and environmental samples for pesticide residues to reduce the number that must be analysed by more elaborate nuclear or related techniques. It is important in residue analysis because of its speed, simplicity and minimal cost (NRI, 1995). This can also be used for screening pesticide residues in samples of unknown origin. The main disadvantages include lower sensitivity than gas liquid chromatography and frequent need for more efficient clean up. In some countries, problems may be encountered when high humidity or temperature cause lack of repeatability.

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Most recent is the use of nuclear and immunochemical methods for pesticide analysis. The enzyme linked immunosorbent assay (ELISA) for pesticide residue analysis has a number of attractions including high specificity and sensitivity. Speed and low cost are further advantages where large numbers of similar samples are involved.

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CHAPTER 3

3.0 FARMERS KNOWLEDGE OF TOMATO CROP PESTS, CROPPING PRACTICES AND PESTICIDE USE PATTERNS IN TWO SELECTED PRODUCTION SYSTEMS IN GHANA.

3.1 Introduction.

Tomato *Lycopersicum esculentum* Mill is increasing in importance due to its popularity in the Ghanaian diet and growing urban markets. One of the major problems of the intensified production is the increasing pest and disease pressure as the use of monoculture and continuous cropping on same land continues to provide favourable feeding opportunities for insects (Kumar, 1986). At high insect infestation, no marketable produce is harvested on untreated crops (FAO, 1988).

The high economic value of the tomato crop makes it tempting to control insect pest solely with chemical insecticides. According to FAO (1989), NARP (1997) and Gerken *et al.*, (2000), very wide range of pesticides are freely available on the Ghanaian market and being used indiscriminately because of lack of information and relaxed regulatory mechanism. The number of pesticides is likely to increase in the future because of the high demand for good quality agricultural products and the urgent need for self-sufficiency in food production.

The prospects of enhancing the farmers' role as an independent decision maker in sound pesticide management practices requires a realistic assessment of production and protection practices on farm. Farmers' knowledge of pest problems and critical time of insect pests infestation are essential considerations for decision making for effective pest management. Information on cropping systems and pest control practices needs to be obtained to appreciate tomato farmers practices and to assess opportunities as well as constraints for

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decision making at the farm level so that appropriate decision tools and designs can be formulated to meet the farmers' need.

The objectives of this study were;

(a) to assess the current knowledge and perception among local farmers of insect pests and pest damage

(b) to identify production and alternative pest management practices that are presently being used or that may potentially be altered or encouraged to minimise pest damage.

(c) to review current pesticide use patterns in two selected tomato production zones.

3.2 Materials and methods:

3.2.1 Study areas.

The questionnaire-based survey was conducted across two agro ecological regions in Ghana under two different tomato production systems. The survey was conducted from January to July 2000. The study areas were Tono and Vea irrigation project areas in the Upper East region covering the Savannah zone and Techimentia, Derma, Dwemo and Duayaw Nkwanta areas in the Tano district of the Brong-Ahafo region covering the forest zone (Fig. 1) where the tomato crop is widely cultivated commercially.

(i) Tono and Vea irrigation areas (UER)

The Tono and Vea irrigation project areas under the management of Irrigation Company of the Upper Region (ICOUR) are in Kassena Nankani and Bolgatanga districts respectively, of the Upper East Region (Fig. 1). This region covers a total of 8,800 km^2 in the north–eastern corner of Ghana

The irrigation project is at 10^o 45' north latitude and 1^o west longitude. The project covers a total irrigable land area of 1,197 ha at Tono and 850 ha at Vea. Irrigation water to the crop areas is supplied by gravity from the dam reservoir through the system of main and lateral

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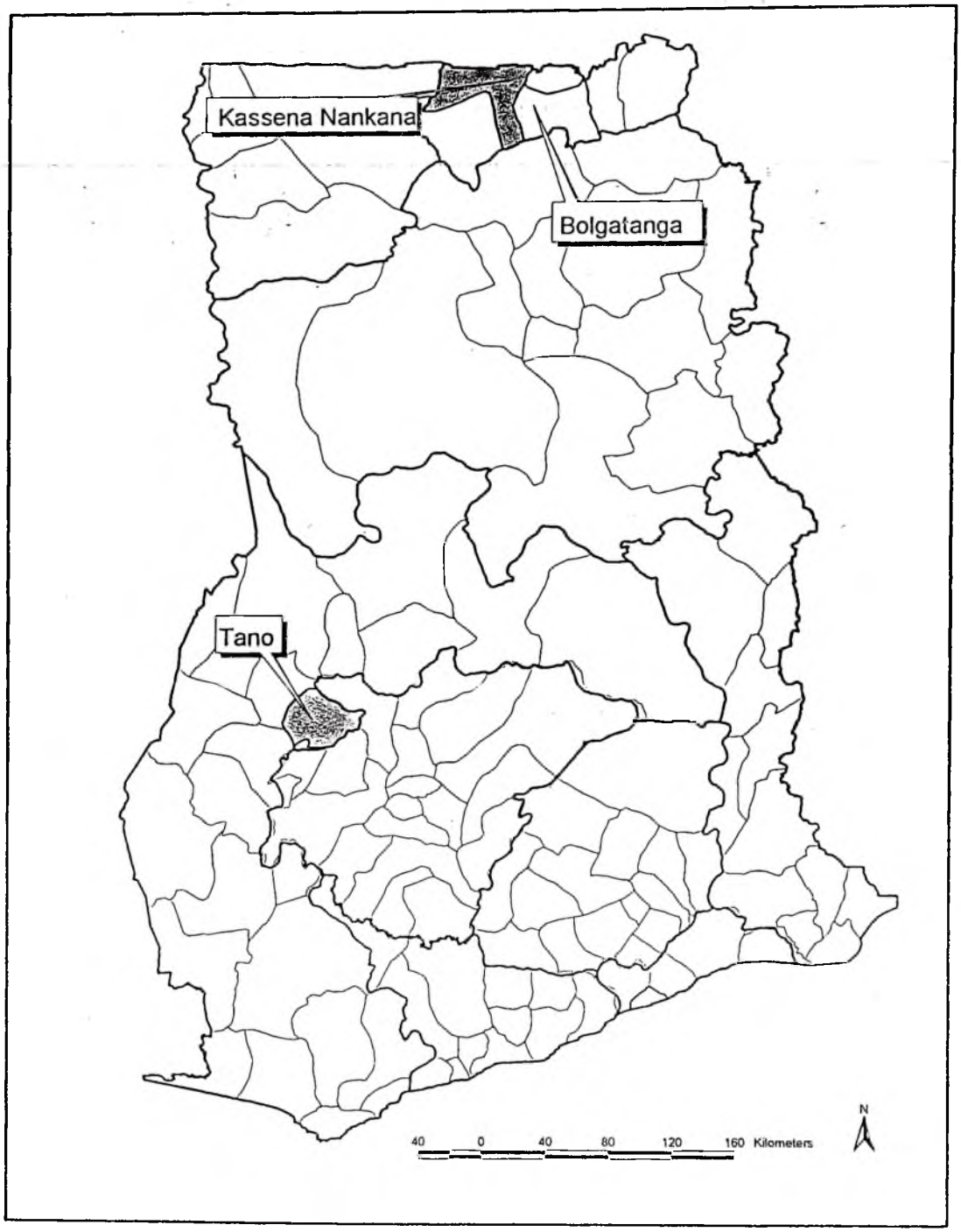

Fig. 1 Map of Ghana Showing Study Areas

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canals. Dry season cropping on irrigated lands consists of pepper, tomatoes, onions, rice, and soyabeans.

(ii) Tano district of Brong Ahafo region

The Tano district is one of the 13 districts in the Brong Ahafo Region of Ghana. It is predominantly rural. As expected of rural economy, agriculture employs about 60% of labour force (Tano District Assembly, 1996). It lies approximately between latitudes 7°00N' and 7°25N and between longitude 1°45W and 2°15W. The district has total land area of about 1,500 km^2, which is 3.798 per cent of the total land area of Brong Ahafo region. It lies in the wet semi equatorial climatic zone which experiences double maximal rainfall pattern and lies in the moist semi-deciduous forest zone.

The estimated population of the district in 1996 was 134,255 (Tano District Assembly, 1996). The thriving tomato farming activities at Techimentia and Derma areas and other food crops continue to attract farmers to the district. Major vegetables grown are garden eggs, tomato, okro and pepper.

3.2.2 Survey

A Knowledge, Attitude and Practice (KAP) type survey (Mumford and Norton, 1993) was pre-tested with the extension agents and farmers at Akomadan, a major tomato growing area in the Ashanti Region and at the Tono Irrigation Project area in the Upper East Region from October to November 1999. These locations represent two different agro-ecological zones and production systems.

After the pre-survey exercise, the questionnaire was refined with other information from previous surveys on use of agrochemicals in vegetable production (NARP, 1992; 1997 and

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Ninsin, 1997) and on Politics and Economics of Pesticide use in Ghana (Gerken *et al.*, 2000).

Important information sought in the questionnaire (Appendix B) included:

(1) Farmer status

(2) Farmers experience and objectives

(3) Cropping systems

(4) Knowledge on pest problems

(5) Methods used to control pests.

(6) Types of pesticides and formulations used.

(7) Frequency of application and spraying intervals.

(8) Concentrations of pesticides used.

(9) Pre-harvest intervals observed

(10) Method of pesticide application and equipment used

(11) Decision making in pesticide use

(12) Protective measures while spraying

(13) Pesticide disposal

(14) Knowledge of side effect of pesticide use.

Questions were related first to the farming structure and to the farmers' socio-demographic characteristics. Secondly, farmers were asked about their ability to identify various production constraints such as tomato pests, and their damage, as well as their awareness of the critical time of infestation, their perceptions of pest importance or pest threat with regard to yield losses and the control measures they employ. Farmers were also asked about their awareness regarding pest management education and training.

The section of the survey relating to the farmers' knowledge about arthropod pest problems was conducted with information showing colour photographs of pests from Critchley (1997)

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book on Vegetable Pests and Manual on tomato and cabbage pests (Varela, 1999). The final part of the survey dealt with pesticide use patterns on tomato and knowledge of associated problems.

3.2.2.1 Choice of respondents:

An informal survey was conducted in the Tano district to determine the major communities where tomato cultivation was concentrated. Communities around Derma, Techimantia Dwemo and Duayaw Nkwanta were selected as major tomato growing areas in the district. Similar surveys were carried out at Tono and Vea to select zones where tomato production was concentrated.

The number of farmers selected for the interview at the communities or zonal level depended on the following:

(i) The intensity of cultivation

(ii) The number of farmers growing tomato in the communities or zones.

In the formal survey at the community or zonal level, a random sample of growers were selected and interviewed. Appointments were made with some of the respondents on farm for the administering of the questionnaires. In all, a total of 120 tomato farmers were interviewed on farm (Table 12). Interviews were conducted together with extension agents of MOFA and were carried out in local languages (Akan, Kasim, Nankane and Gruni).

Respondents were farmers who had started pesticide application and are harvesting or near harvesting to ensure that all farm operations would have been carried out already before the interview.

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Table 12: Number of respondents interviewed in two selected tomato growing areas.

Growing Areas	Villages/community	No. of Respondent
1. Tono and Vea irrigation Areas (Savannah zone)	(i) Vea	20
	(ii) Nyariga	10
	(iii) Sambrungu.	10
	(iv) Tono	30
	Total for Savannah zone	60
2. Tano District (Forest Zone)	(i) Duayaw Nkwanta	10
	(ii) Dwemo	10
	(iii) Techimantia	20
	(iv) Derma	20
	Total for Forest zone	60
Grand Total		120

3.3 Results and discussion

3.3.1 Demographic characteristics

The farming systems in the two production zones are represented by small-holdings among which tomato areas ranged from less than 0.2 ha to 4.0 ha (Fig 2). In the Upper East region (UER), 81.5% of farmers' holdings were in the range of 0.2 ha. to 1.2 ha. High levy charges on water and land restrict farmer holdings to less than 1.2 ha at Tono and Vea Irrigation areas. In the forest zones (Tano district) of the Brong Ahafo region (BAR), 90.5% of farmers surveyed had their farm holdings ranging from 0.2 to 1.2 ha (Fig 2).

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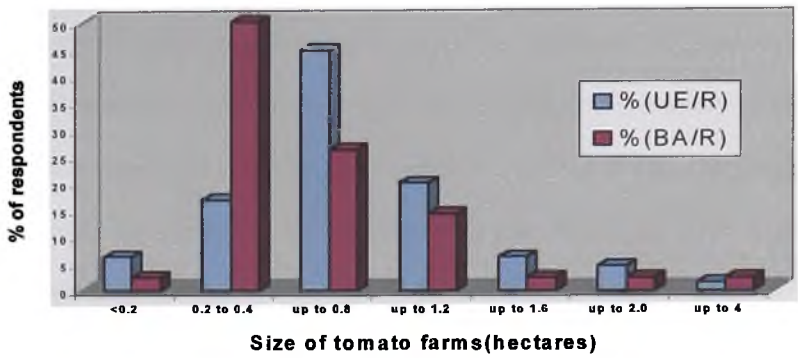

Fig. 2 Distribution of tomato farmers farm size

The survey revealed a wide range of ages. Overall, 80.0% of the farmers were more than 30 years at the Tono and Vea Irrigation Project areas. About 69.0% were between 30 - 50 years, representing the most active farming group in the region. Similarly, in the forest zones, 60.1% of respondents were above 30 years of age. On the average, 47.5% of the farmers were in the active age group of 31 to 40 years (Fig 3). The two production systems had more males than female farmers. Only 2.3% and 1.8% represented female farmers in the BAR and UER, respectively. The reasons were that tomato production is labour intensive and female farmers normally hire labour to undertake difficult farm operations.

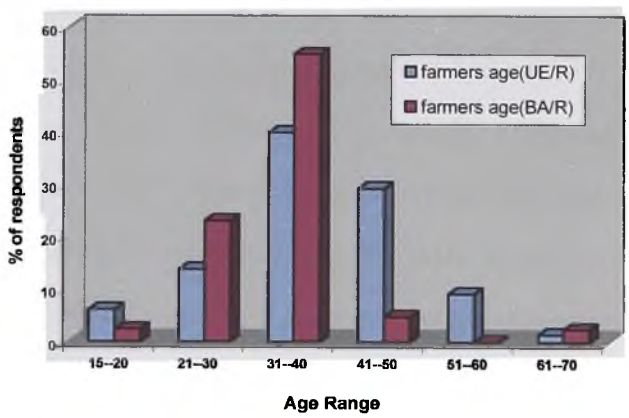

Fig. 3 Distribution of tomato farmers' ages

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Most farmers had no basic education. In the UER, 33.8% were illiterate and 24.6% had only non-formal education. Overall, only 9.2% had education up to tertiary level (Fig. 4). In the Brong Ahafo region, 7.1% of the farmers were illiterates, 2.4% non-formal education, 76.2% of the farmers had education up to middle school level and only 2.4% had education up to tertiary level (Fig. 4).

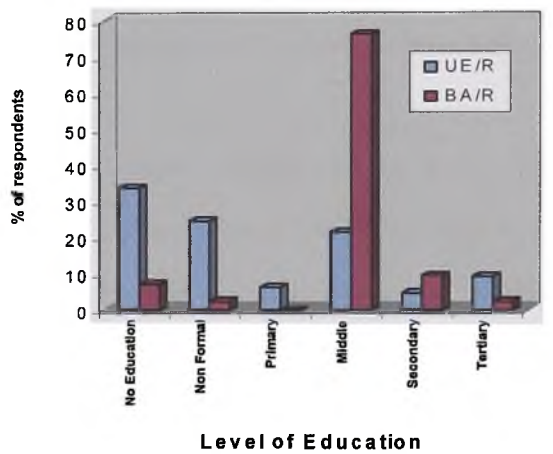

Fig. 4 Distribution of tomato farmers' level of education

3.3.2 Farmers experience and objectives

In the savannah zone (UER), about 75.4% of farmers had experience of up to 10 years in growing tomato. 44.6% of the farmers interviewed had only 1 - 5 years experience of growing tomato, an evidence of the recent increase in the production of the crop (FAO, 1999). Only 7.7% and 13.9% of respondents were in production for 11 – 15 and 16 – 20 years in the UER and BAR, respectively (Fig. 5). In the forest zone, 69.1% have experience ranging from 1 10 years. Only 4.7% of farmers had grown tomato for more than 20 years Fig. 5).

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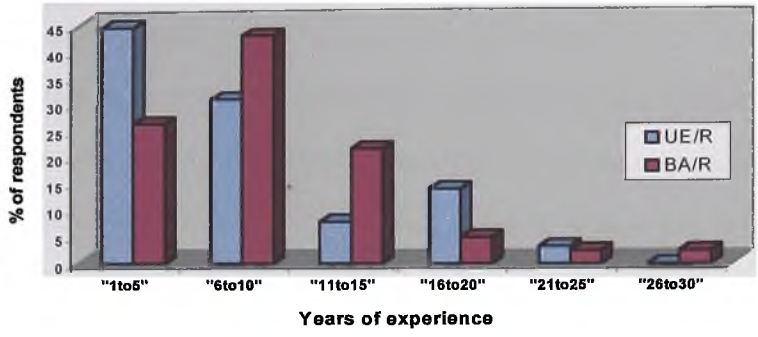

Fig. 5 Distribution of farmers' years of experience in growing tomato

The most active age among farmers cultivating tomato is 30 – 40 years, which comprise farmers of not more than 10 years of farming experience. This constitutes about 40.0% and 54.8% of active farmers in the UER (savannah zone) and BAR (forest zone), respectively. These indicate that every year new farmers are attracted to the cultivation of tomato crop under both production systems. This explains the increase in production areas from 16, 000/ha in 1995 (Nurah, 1999) to 30,000/ha in 1998 (FAO, 1999).

The main reason why farmers grow tomato was for cash as tomato crop provides a cash return within a very short time compared to other crops. The cultivation of the crop is further enhanced in the savannah zone between November and April as national supply generally decreases during the dry season in the Brong Ahafo and Ashanti regions (Lyon *et al.*, 1998).

Farmers' income in terms of margins after disbursement of inputs ranged from ¢1.48M to ¢3.0M per hectare in the UER and on the average, net returns for the 1999/2000 irrigated cropping season averaged ¢1.0M per hectare among 56 tomato farmers interviewed in the UER.

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3.3.3 Cropping system

Tomato is planted generally in monocultures in both production systems. Land is rarely allowed more than a year to lie fallow in the UER. Within the year tomato is rotated with either soyabeans, groundnuts, millet or sorghum during the rainy season at the Tono and Vea project sites. In the forest zone of the Brong Ahafo region ((BAR), about 86% of farmers interviewed rotate their fields every two years. Land is either planted with cassava or left fallow for a period of about two years. There is therefore a potential for small-scale tomato farmers to adopt crop rotation or fallowing as a sustainable pest management strategy. The various agronomic practices in the two production zones are indicated in Table 11.

(i) Source of water

Water is obtained from the dams, dugouts and rivers during the dry season. Generally, fields are irrigated at 3 – 5 day intervals under both production systems during the dry season. Production is a whole year activity in the Brong Ahafo region.

(ii) Source of seeds

Among tomato farmers interviewed in the Upper East region, 84.6% of the respondents obtained their seeds from registered seed retailers and agricultural institutions such as FASCOM and ICOUR who supply certified seeds for farmers in the region (Fig. 6). Seed treatment with chemicals such as Apron – plus (Furathiocarb + carboxyl + metalaxyl) and Marshal (carbosulfan) were used. This practice implies that farmers are aware of the need to use clean and certified seeds under irrigation in the Upper East region where higher yields of 16.6 ton/ha are possible compared with yields as low as 3.6 tons/ha in some areas of Brong Ahafo Region (Nurah, 1999; Wolff, 1999).

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Table 13: Summary of tomato cropping systems in two production zones of Ghana

Activities	Forest zone (Techimentia , Derma, Dwemo and Duayaw Nkwanta	Savannah zone (Tono and Vea)
Nursery	Seed varieties: Power, Italy, Reno, Yokohama. Rasta. Remarks: Uncertified. Source: Own extraction and from friends Watering at least every 3 days in the dry season from rivers.	Seed varieties: Petomech, Titano Roma, and "No name" Remarks: Certified. Source: Registered dealers, ICOUR and FASCOM. Irrigation from dams and rivers at 3 - 7 days intervals.
Land preparation	Slashing, burning, gathering and Ridging	Ploughing, harrowing and ridging
Transplanting	Seedlings transplanted on ridges at 3 – 4 weeks old. Re-ridging 2 weeks after transplanting	Seedlings transplanted on side of ridges at 3 – 5 weeks old.
Fertilization	NPK applied once while re-ridging with a stick. Foliar fertilizer applied weekly. Ammonia optional. Organic fertilizers absent.	NKP applied 2 - 3 weeks after transplanting Foliar fertilizers and growth regulators applied 1 – 2 weekly. Ammonia applied. Farm Yard Manure seldom used.
Pesticide application	Mostly calendar spray between 6 – 12 times Mostly as cocktails of insecticide fungicides + foliar fertilizers. Insecticide mixtures are commonly applied. Cocktail differ according to the biological stage of the plant. Systemic and contact fungicides are mostly used. Petrol – powered spraying machines are preferably used	Calendar spraying 3 – 6 times per cycle. Mostly as mixtures of insecticide + fungicides+ foliar fertilizer + growth regulators Systemic and contact fungicides are used but less Dithane used by few farmers for cosmetic purpose or after a sudden downpour at the end of season Manual spraying machine (knapsack) used
Weed control	Manually by weeding with a cutlass or while ridging with a mattock Herbicides are not applied	Manually weeding with hoe and hand. Herbicides are not applied
Other cultural practices	Re- ridging is mostly done once, staking not known	Re-ridging is not done, staking not known

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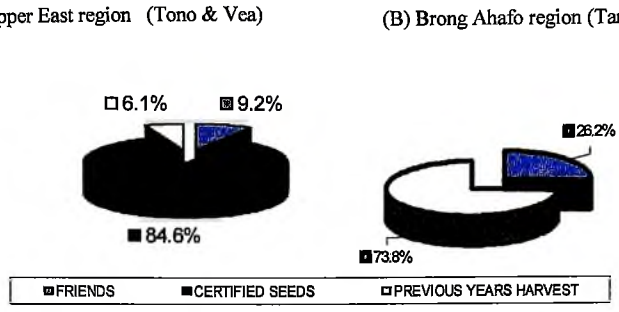

Fig. 6 Farmers source of tomato seeds under the two production systems

On the contrary, the survey revealed that most farmers use local varieties of tomato seeds in the Tano district (forest zone). Farmers source of seeds revealed the following; 73.8% from previous years harvest and 26.2% from friends (Fig 6). Farmers do not treat their seeds before nursing. The risk of harbouring seed borne pathogens is therefore high and has the potential of transmitting plant diseases, which have been identified as main production constraint in the Brong Ahafo region. Generally, farmers interviewed grew two or three different types of tomato varieties during the season. The main varieties grown in the Upper East region were Petomech, Roma, Titano and "No name ". The most preferred variety is Petomech, which was grown by 87.7% of respondents either solely or in combination with other varieties in phases (Fig. 7).

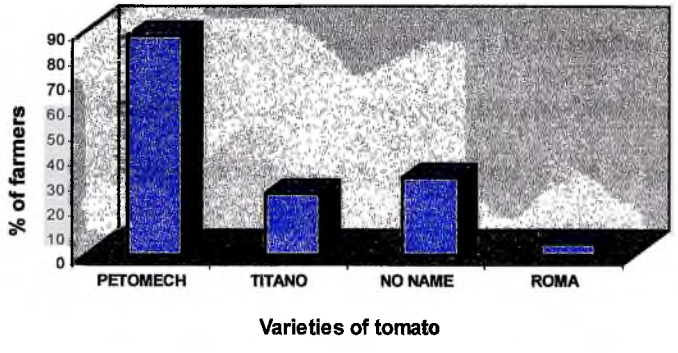

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Fig. 7 Varieties of tomato grown by farmers in the UER

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Most farmers expressed the opinion that these varieties were preferred because of good attributes such as high yielding, medium shape and firmness which are desirable qualities preferred by the market women who buy the fruit at farm gate to the urban centres.

In the forest/transition zone in the Brong Ahafo region (Tano district) over six different varieties and cross breeds were popular among the farmers. These were cropped either singly or in combinations. Some varieties cultivated were Italy (40.0%), Power and Power – Reno (66.6%) (a cross between Power and Laurano) (Fig. 8). According to Wolff, (1999), Power

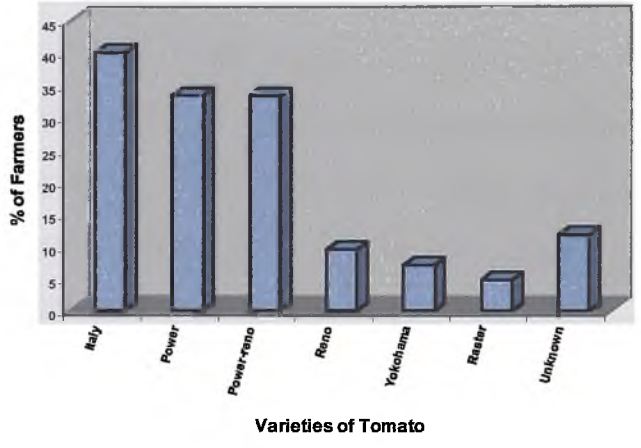

Fig. 8 Varieties of tomato grown by farmers in the BAR

has been cultivated since 1960, and it is therefore quite possible that it has adapted to the climatic conditions and fits into the production system in the forest/transitions zones. With the growth of commercialised vegetable production, farmers have become more 'insect conscious' and perceive new varieties as being more susceptible to pest problems in the Brong Ahafo region.

In the Upper East region about 35.39% of farmers cultivated a mixture of two or three varieties whilst, 63.08% of farmers cultivated one variety at a time. Also, 54.8% of farmers cropped one variety in the Brong Ahafo region. By mixing different tomato varieties,

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farmers reduce the risk of production loss if one variety should fail. Furthermore, the marketing risks are reduced because farmers can be more flexible to the particular demands, especially in times of glut. The combination of different varieties is evaluated positively as an IPM measure since it has various positive effects on the incidence of pests and diseases.

3.3.4 Farmers ability to identify pest and pest damage.

Among well-known insect species, were the tomato fruit borer *Helicoverpa armigera* (Hubner) and the variegated grasshopper *Zonocerus variegatus* (L). These pests were easily identified by 89.23% and 70.76%, respectively of farmers interviewed in the Upper East region whereas 100% of farmers in the forest zone indicated the presence of these pests on their tomato crop all year round. This is because these polyphagous insects occur more frequently, are easily apparent in the field and their damage are clearly distinguished (Critchley, 1997) (Plates 1).

Most farmers admitted that from the nursery-stage through the vegetative stages, grasshoppers caused the most damage especially in the forest zones. With regard to the fruit borer, farmers distinguished between different stages of infestation. Most farmers were able to recognise the insect infestation on fruits as they bore into the fruits. Few farmers were able to trace infestation of flowers and buds to *Helicoverpa armigera* resulting into flower abortions and abscission. About 90% of the farmers answered that fruit borer attack corresponds to the fruit formation stage. This recognition is important for decision making to control pest at the early instar stages.

Pest such as aphids *Aphis gossypii*, plant bugs *Nesidiocoris tenuis,* whiteflies *Bemisia tabaci* and African mole cricket, *Gryllotalpa africana* were not well known in the Upper East region as these insects are hardly seen on tomato in the fields. *N. tenuis* were identified by only two

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Plate 1. Fruitworm damage on unripe green fruit

Plate 2. Leafminer damage on tomato leaves

Plate 3. Tomato attacked by unknown disease

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farmers participating in IPM/Farmers Field Schools (FFS) training programme at Vea irrigation project areas under the UNDP Poverty Reduction Programme in the Bongo district of the Upper East region. Eggs of major pests were totally ignored by farmers because most eggs are too small to be readily visible.

On the contrary, farmers perceive *N. tenius* as a major pest of tomato in the forest/ transitional zone of Ghana. These bugs suck sap from the plant at the growing points or truss and girdle around leading to collapse of terminal shoots and eventual drop of flowers. The presence of the pest throughout the cropping season attracts continuous applications of chemicals by farmers, contrary to reports by Forsyth (1966) and Critchley (1997) describing the bugs as minor pests on tomatoes. Actual damage level needs to be assessed to justify the current control interventions directed against this pest in the forest/ transition zones.

The whiteflies, which have been documented as major pest of vegetables in Ghana in recent times (Critchley, 1997), was completely not mentioned nor identified by farmers as major pest of tomatoes in the Upper East region. Pest survey throughout the season indicated non-prevalence of the pests on tomato crop in the Upper East region. However, prevalence of the pest in the forest region is widespread. Specific damage could not be ascertained by farmers interviewed but could be linked up to widespread viral diseases on tomato in the forest/transition zone.

Farmers did not identify the leafminer *Lyriomyza spp* as a major pest even though symptoms of their damage were apparent in scattered locations on farm (Plate 2). Farmers probably consider their damage as insignificant. Damage by termites and cutworms *Agrotis upsilon*, were identified in some scattered localities on farm under the two production systems.

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3.3.5 Farmers' perception of insect pests and their awareness of yield losses due to major insect pests

According to the farmers, the most frequent pests or damage in their fields were attributed in order of importance to the fruit worms *H. armigera* and leafworm S. *littoralis*; grasshoppers *Z. variegatus*, and plant bugs *N. tenuis*, the cotton aphids *Aphis gossypii* and whiteflies *Bemisia tabacci* in the Brong Ahafo region. The survey found that the fruit worms *H. armigera* and *S. littoralis* were the most serious pests of tomato in Ghana. With regard to yield loss, farmers attributed yield loss in terms of infested whole fruits mostly to the fruit worms. These worms reduce yield even under protected condition and varying degree of losses were perceived by farmers ranging from 5 % - 40% even under protected condition with routine insecticides applications.

This awareness of pest threat led them to increase the frequency of application of chemicals to minimise pest impact on yield without any regard to pest status and critical time of infestation. They believed that applying more treatments would reduce flower and fruit damage due to the pests and thus lead to increase in the yield of tomato fruit. However, farmers were of the view that yields losses range from 50% 100% when no insecticide is applied. About 18.6% of respondents in the forest/transition zones perceived that a total loss (100%) in yield is likely if insecticides are not applied at all.

3.3.6 Farmers' perception of pest control methods.

All of the farmers interviewed (100%) indicated that they prefer chemical methods to control all insect pests on tomato to any other alternative methods. This opinion is influenced by the fact that chemical control provides quick action against the insects. This confirms the findings of similar studies by Brempong-Yeboah (1992), Larbi (1997) and Gerken *et al.*,

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(2000). The major reason of farmers preferring pesticides instead of other plant protection measures was their interest in "rapid" results in contrast to long-term control measures. Traditional method of using wood ash was applied by only 5.5% of respondents in a Brong Ahafo region to control insect pests. This was applied with other pesticides as mixtures. Only one farmer in the Tano district applied neem products and pepper on tomato crop to control leaf-feeding insects.

Few farmers practiced cultural methods such as removal of infested fruits and crop rotation. In the Brong Ahafo region, farmers distinguished between two types of chemicals; "Poison" which include all liquid insecticides and "powder" which includes all fungicides and foliar fertilizers. Farmers often use "Poison" to kill insects. It is unlikely that farmers distinguish between different insecticides and fungicides for different insect pests and disease problems. Some farmers admitted that certain pests and their development stages were not well controlled. They cited pest such as caterpillars, mites, grasshoppers, aphids, and the fruit borers, probably due to the low dose, resistant development, wrong timing and/or the use of contact insecticides, which are ineffective in controlling fruit borers and sucking insects.

3.3.7 Pesticide use pattern in tomatoes:

Under both production systems, commercial farmers rely almost entirely on chemical control as intensification of production demands more use of agricultural inputs for the successful cultivation of the tomato crop. Development and use of pesticides is now a big business. According to Van den Bosh, (1978), the considerations are mainly profits with insufficient thought given to environmental hazards and toxic effects.

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3.3.7.1 Types of pesticide formulations used

(i) Insecticide

The survey revealed that tomato farmers in the Upper East region applied 15 different insecticide formulations (Fig 10a). All except two of the formulations; Baythroid P 168 EC and Deltaphos 262 EC are not approved in Ghana. In the forest zones (Techimentia, Duayaw Nkwanta, Derma and Dwemo) in the Tano district of the Brong Ahafo region, 13 insecticide formulations were used for which seven of these products are either not approved or have restricted use in the country with reference to EPA approved pesticide list (Yeboah, 1998). These unapproved and restricted products are Deltaphos 262 EC, Cypercal P186 EC, Decis D 312 EC, Polythrin 336 EC, KD, Thiodan 50 EC and Thionex 35 EC/ULV. Among the insecticides applied, organochlorine was made up of 23.1% and 13.3% of insecticide formulations used in the BAR (Tano district) and UER (Vea and Tono), respectively (Fig. 9). The most important insecticide used was Karate 2.5 EC (Lamdacyhalothrin), in which 75.3% and 28.57% of the farmers used in the Upper East and Brong Ahafo regions, respectively (Fig 10a and 10b). This is in agreement with previous surveys by NARP (1997) and Gerken *el al.,* (2000) where farmers showed high preference for Karate 2.5 EC insecticide probably because of low rate of application and quick knockdown effect associated with the synthetic pyrethroids. The high usage is confirmed with information on the import statistics of pesticides, which ranked Karate as number 3 in the Ghanaian pesticide market (Gerken *et al.*, 2000).

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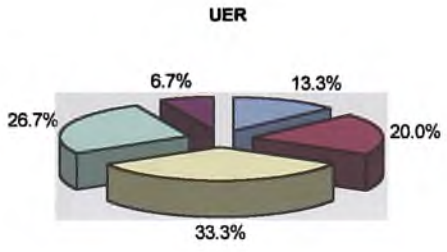
(a)



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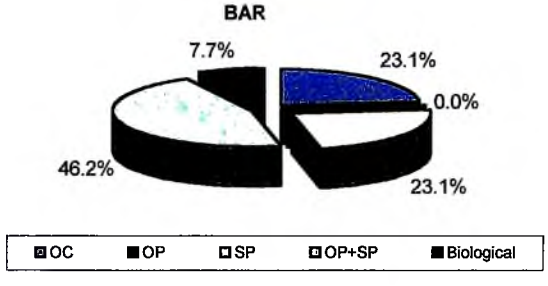

Fig. 9 Distribution of insecticide formulations according to chemical class applied by tomato farmers

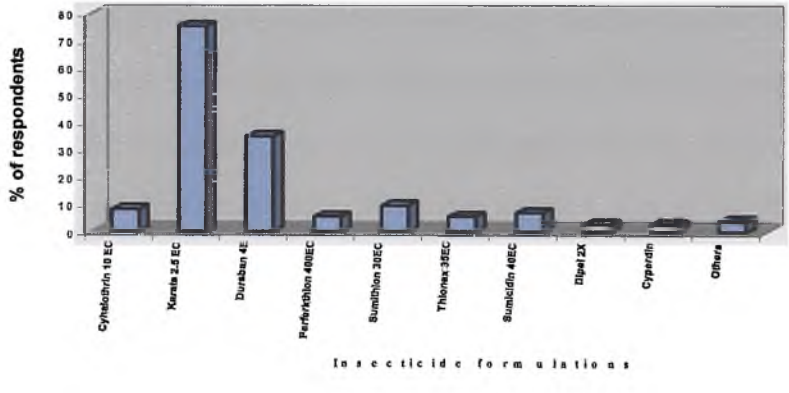

Fig. 10a Distribution of insecticides formulations used by tomato farmers in the UER

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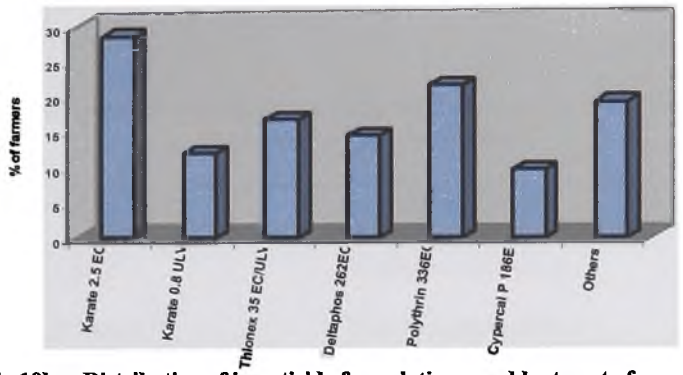

Fig.10b Distribution of insecticide formulations used by tomato farmers in the BAR

The survey showed the indiscriminate use of Thiodan 50 EC, Fenom C, Deltaphos 262 EC, Thionex 35 EC/ULV, Cypercal P 186 EC, Polythrine 336 EC, KD, Baythriod 168 EC, Karate 0.8% ULV and Gamallin 20 EC (Fig 10a &b). These are highly concentrated insecticide formulations with restricted usage only on cotton and cocoa. The insecticides Deltaphos 262 EC, Polythrin 336 EC, Baythroid P 168 EC, Cypercal P186 EC, Decis D 312 *EC* and KD were all in French labels. The fact that the relevant information concerning the safe and effective use of these products are written in French only suggest that these formulations found their way from the neighbouring francophone countries into the Ghanaian market. A cross checks at the retail shops in the Tano district confirmed the fact that these products were openly sold in the Ghanaian market. Not only were their prices relatively cheaper but also some had expired and therefore obsolete. From two inventory surveys in Ghana, obsolete stocks owned by government establishments, farmers services companies and private retailers increased from 50 tonnes in 1997 to 71 tonnes in 2000 (FAO, 1997; 2000). This has tremendous implication on safe pesticide usage if appropriate disposal options are not put in place to` get rid of these obsolete pesticides which find their way in the pesticide market.

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Table 14: The different formulations and active ingredients of the insecticide products applied on tomatoes.

Product name	Ingredients Active
Karate 2.5 EC [ab]	*Lambda cyhalothrin*
Karate 0.8% ULV [ab]	*Lambda cyhalothrin*
Cyhalon IO EC [ab]	*Cyhalothrin*
Dursban 4E [a]	*Chlorpyrifos*
Perferkthion 400 EC [a]	*Dimethoate*
Sumithion 40 EC [a]	*Fenitrothion*
Thionex 35 EC/ULV[ab]	*Endosulfan*
Thiodan 50 EC[ab]	*Endosulfan*
Cyperdim [a]	*Cypermethrin + Dimethoate*
Sumicidin 20 EC [a]	*Fenvalerate*
Deltaphos 262 EC [ab]	*Deltamethrin + Triazophos*
Fenom C [ab]	*Cypermethrin+Profenofos*
Baythroid P 168 EC[a]	*Cyfluthrin* + Profenofos
Sumi-Alpha 5 EC [a]	*Esfenvalerate*
Dipel 2X [ab]	*Bacillus thurigiensis sub sp kurstaki*
KD [b]	*Lamdacyhalothrin + Chlopyrifos methyl*
Polythrin 336 EC[b]	*Cypermethrin + Chlorpyrifos methyl*
Cypercal P 186 EC[b]	*Cypermethrin + Profenophos*
Decis D 312 EC [b]	*Deltamethrin +Chlorpyrifos methyl*
Gamallin 20 EC[b] (Gamma BHC)	*Lindane*

[a] refers to insecticide used in UER

[b] refers to insecticide used in BAR

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According to NARP (1993), vegetable farmers choice of pesticide formulations is depended on the cost. With the present escalating cost of agro–chemicals in the country, only a few farmers can afford to buy the recommended pesticides. Consequently, most farmers use any pesticide they lay hands on, which may either be the wrong chemical, may be wrongly applied, or the wrong equipment may be used (NARP, 1993). The relaxed legal control with regards to registration and usage of pesticides provides incentive for the smuggling into the country (NARP, 1993; 1997; Ninsin, 1997). This violates the Pesticide Control and Management Act 528 (1996) of Ghana, which is still not fully being enforced. According to Youm *et al.*, (1990), the relaxed legal control on pesticide import, distribution, sale, advertising, registration and low literacy rate among farmers and inadequate extension services have also contributed to the regular and widespread mis-use of pesticides (Bull, 1982).

The use of organochlorine insecticides (Endosulfan) marketed as Thiodan 50 EC and Thionex 35 EC/ULV for tomato production is currently on the increase (Fig 9a & b). This product is banned in many countries, while campaigns for banning its use are going on in others (Pesticide News, 2001). According to Pesticide News (2001), Endosulfan was introduced in cotton production all over francophone West African over the 1999/2000 season, as part of a West African regional programme to combat pyrethroid resistance of the American bollworm *H. armigera.* However, this product has a reputation as a highly toxic and dangerous pesticide, particularly under poor spraying conditions without the use of protective clothing. For instance, official source in Benin states that at least 37 people died over the 1999/2000 seasons while another 36 people experienced serious ill health from endosulfan poisoning (Pesticide News, 2001).

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According to Oudejans (1982), endosulfan should not be used on edible crops within 30 days of harvesting. Their characteristics of persistency, low solubility in water and wide spectrum insecticidal activity, have already provoked legislation that restricts their use in many countries. The versality of the organochlorines, their availability in the Ghanaian market and relatively low cost pose serious risk of misapplication by farmers for vegetable pest control.

The survey revealed varying patterns of combination of insecticide products under both production systems. In all 68.5% of respondents used different formulations of insecticides as single spray contrary to general opinion that vegetable farmers use "cocktails" of different insecticides at the Tono and Vea irrigation project area. This can be attributed to a relatively better technical knowledge on the part of farmers under irrigated farming in the Upper East region due to greater extension coverage and expert advice from network of ICOUR extension personnel's and MOFA agricultural extension agents operating in these farming zones.

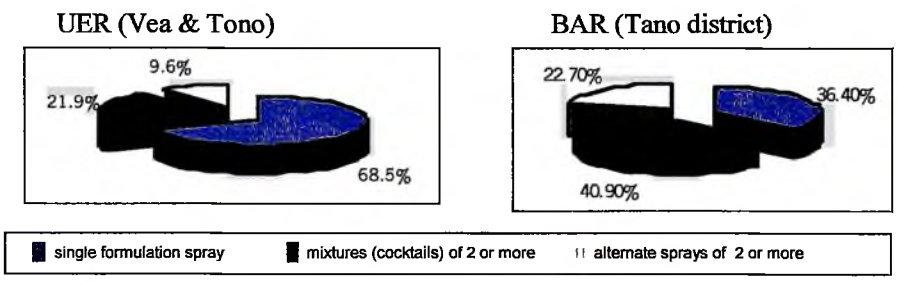

Fig. 11 Patterns of combinations of insecticide formulations sprayed on tomato under two production systems in Ghana

On the contrally, most farmers interviewed in the Brong Ahafo region used two or more insecticide formulations as "cocktails". In all, 63.6% of respondents used two or more insecticides as mixtures and alternative sprays (Fig 11). In most cases, chemicals with the

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same active ingredient and / or of the same chemical groups and different formulations were mixed together for spraying.

For example, the pyrethroid insecticide Karate 2.5 EC was commonly mixed with Karate 0.8% ULV of the same active ingredient (Lamdacyhalothrin) but different formulations. Also, Karate 2.5 EC (Lamdacyhalothrin) and Cyhalon10 EC (Cyhalothrin), an isomer were often mixed together. The different combinations of mixtures of insecticide formulations sprayed on tomato under both production systems were;

1.	Karate 2.5 EC and Cyhalothrin 10 EC	(SP + SP)
2.	Karate 2.5 EC and Dursban 4E	(SP + OP)
3.	Karate 2.5 EC and Dipel 2X	(SP + Biological)
4.	Karate 2.5 EC and Cyperdim	(SP + SP + OP)
5.	Karate 2.5 EC and Sumithion 10 EC	(SP + OP)
6.	Karate 2.5 EC and Sumicidin 20 EC	(SP + SP)
7.	Karate 2.5 EC and Thionex 35 EC	(SP + OC)
8.	Karate 0.8% ULV and Thionex 35 EC/ULV	(SP + OC)
9.	Karate 2.5 EC and Thiodan 50 EC	(SP + OC)
10.	Karate 2.5 EC and Cypercal P 183 EC	(SP + SP + OP)
11.	Karate 2.5 EC and Karate 0.8% ULV	(SP + SP)
12.	Karate 2.5 EC and Polythrin 336 EC	(SP + SP + OP)
13.	Karate 2.5 EC and Sumicidin 20 EC and Cyhalothrin 10 EC	(SP + SP + SP)
14.	Karate 2.5 EC, Dursban 4E and Cymethoate	(SP + OP + SP + OP)
15.	Karate 2.5 EC, Thionex 35 EC/ULV and Decis	(SP + OC + SP)
16.	Thionex 35 EC and Baythroid P 168 EC	(OC + SP + OP)
17.	Deltaphos 262 EC and Polythrine 336 EC	(OP + SP + OP)

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18. Polythrin 336 EC and Thionex 35 EC (OP + SP + OC)

19. Fenom C, Deltaphos 262 EC and K. D (OP + SP + SP + OP + SP + OP)

20. Deltaphos 262 EC, Polythrine 336 EC and Cypercal P 183 EC (OP + SP + OP + SP + OP + SP)

21. Deltaphos 262 EC and Thionex 35 EC/ULV (OP + SP + OC)

22. Gamallin 20 EC and Cypercal P 183 EC (OC + OP + SP)

The use of different combinations of insecticides may have contributed to the increase in the incidence of insect pest infestation of tomato. This is because this practice defies some of the basic principle of insecticide management, which aims at delaying the onset of insecticide resistance, or more realistically preserving the susceptibility in the target insect pests (Metcalf, 1980).

Metcalf (1980) recommends the following pesticide management strategies:

(1) The use of mixtures of insecticides must be avoided. This is important since mixtures of insecticides generally results in the simultaneous development of resistance, as each compound seems to develop the residual inheritance of supporting genome for resistance in the other.

(2) Extend the useful life of insecticide as long as possible, but monitor susceptibility and replace the insecticide before control fails.

(3) Choose a sequence of suitable alternative insecticides based on genetic considerations affecting cross-resistance and multiple resistance.

Tomato farmers defy these basic principles and apply a combination of different insecticide formulations against polyphagous pests such as *H. armigera*, which is documented to have

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developed resistance to the major classes of insecticides in many of the areas where these have been used. Field failures resulting from pyrethroid resistance have been reported from Australia, Thailand, Turkey, Indian, Indonesia and Pakistan (Vassal *et al.*, 1997). Though there is no documentation of *H. armigera* resistance to insecticide in Ghana, most aphids populations studied on vegetables from 1995 to 1999 were classified as moderately resistant or resistant to pyrethroids (Owusu, Personal Communication).

b. Use of fungicides, foliar fertilizers and plant growth regulators.

Generally, under both production systems, a cocktail of two or more products usually insecticides, fungicides, growth regulators, and foliar fertilizers were mixed with little or no regard to their toxicity or the manufacturer's recommended rate of application. Fungicide usage was less in the Upper East region than the Brong. Only 23.2% of farmers used five different fungicides, which were both contact and systemic in contrast to 100% of farmers in the Brong Ahafo region who used seven fungicide formulations. These were Topsin 70 WP, Benlate, Kocide 101, Dithane M 45, Cobox WP, Nordox and Cocobre (Table 15).

Generally, farmers' knowledge on the correct use of fungicides in terms of the correct methods of preparation and application and the types of fungicide to use was poor. Fungicides were not used necessarily to control diseases, but because they produced luxuriant vegetative growth for cosmetic value. In the Upper East region the use of Dithane M 45 (Mancozeb) in the opinion of farmers was to hasten ripening and for cosmetic appearance when prevailing market prices are high. This observation confirms the observation in Brong Ahafo region that "Powder" (fungicide and fertilizer) appears to be used interchangeably to keep the plants looking healthy rather than to treat specific fungal diseases. In most cases, the chemical used may be inappropriate. Foliar fertilizers and

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growth regulators used by farmers included Grofol, Superfos, Samppi, Cropmax, Biozyme TF, Bionex, K-fol, and Lobbi.

Table 15: Fungicide use pattern under two tomato production systems in Ghana.

[a]Product name	A. I.	UER Respondents 56	% usage	BAR Respondents 52	% usage
A. Systemic					
Topin 70 WP	Thiophanate methyl	2	3.6%	15	32.6%
Benlate	Benomyl	2	3.6%	15	32.6%
Ridomil	Metalaxyl	1	1.8%	6	11.5%
B. Contact					
Kocide	Copper Hydroxide	1	1.8%	16	34.8%
Dithane M 45	Mancozeb	7	12.5%	41	89.1%
Cobox WP	Copper oxy chloride	Nil	Nil	2	4.3%
Nodox	Copper oxy chloride	Nil	Nil	1	2.2%
Cocobre (Sandoz)	Nil	Nil	Nil	1	2.4%

[a]multiple responses

3.3.7.2 Frequency of application

The survey indicated that farmers sprayed more frequently in the Brong Ahafo Region (forests zone) than the Upper East Region (Savannah zone). The high frequency in Brong Ahafo region can be attributed to climatic factors which favour insect pests and disease development and their strict adherence to calendar sprayings. Climatic conditions such as high relative humidity and frequent rainfall in some parts of the year render pesticides ineffective as surface pesticide may be washed away. 40.5% of farmers sprayed between 10

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– 12 times cocktail of pesticides in the Brong Ahafo region while 61.54% of the farmers sprayed up to 4 - 6 times in the Upper East region (Fig. 12). Farmers perceived disease and insect pests' problems as major production constraint in the Brong Ahafo region necessitating more frequent applications of cocktail of insecticides and fungicides to protect their crops.

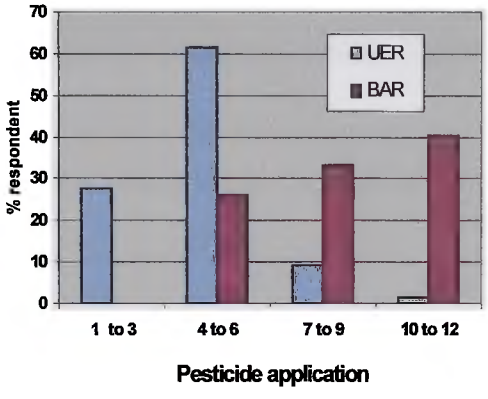

Fig 12 Farmers' response to frequency of pesticide application

3.3.7.3 Spraying intervals observed

Farmers' responses to spraying intervals varied slightly. 66.3% of the farmers sprayed at 3 – 7 day's intervals in Upper East region whereas 83.3% sprayed at similar intervals in the Brong Ahafo Region (Fig 13). Farmers generally perceived that the short spraying intervals are meant as preventive measures and directed at surviving pests following previous application. Some farmers also indicated that the potency of chemicals diminishes after one week. These reasons influence their judgement for the short spraying intervals based on calendar spraying without any regard for pest monitoring as decision tool for pesticide application. These observations were confirmed by Brempong Yeboah (1992) and Ninsin (1997), who reported that vegetable growers sprayed at very short intervals in Southern Ghana. Considering the growers choice and use of pesticide products, there is growing

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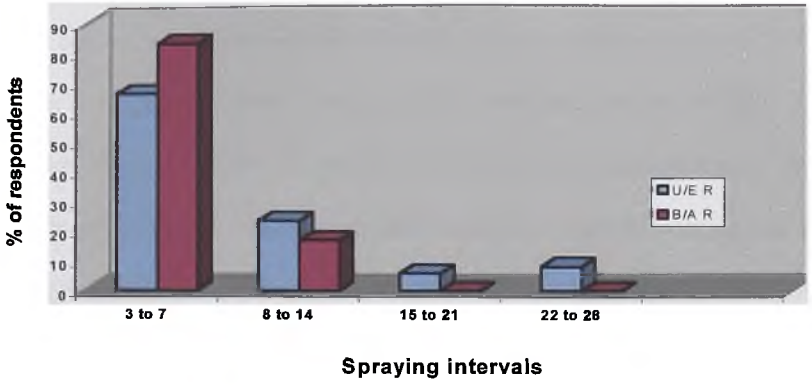

Fig. 13 Spraying intervals observed by tomato farmers

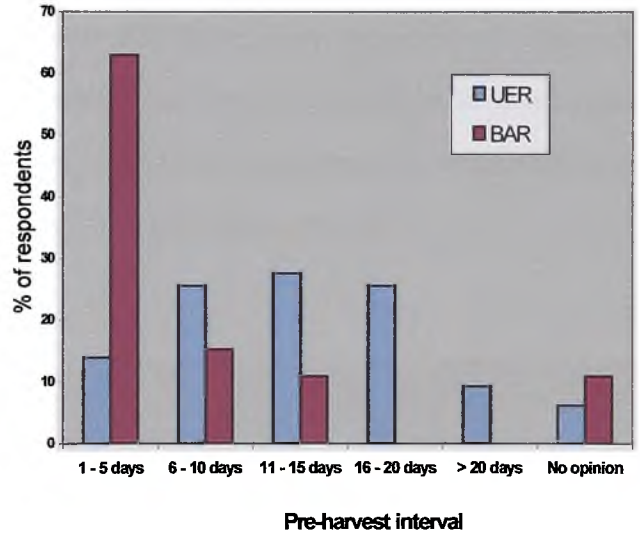

Fig 14. Pre-harvest intervals observed

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possibility of resistance development of key pests including the fruit borer, which is globally documented to have developed resistance to known pyrethroid insecticides.

The rational use of pesticides should be based on a critical action threshold, which determines the timing of treatments (Pedigo, 1989). Since information on action threshold for the management of major tomato pests such as *H. armigera* is not available at farmers level, the rational use of insecticides will require further studies to determine practical and realistic action threshold levels for major pests such as *H. armigera, A. gossypii N. tenuis and B. tabaci* for their management in future IPM programmes in tomatoes.

3.3.7.4 Pre-harvest intervals observed

The survey revealed that pre-harvest intervals were normally not respected. The PHI of 1-5 days was observed by over 60% Brong Ahafo region farmers. However, PHI for most organochlorine and organophosphate insecticides approved in Ghana ranged from 7 – 21 days (Yeboah, 1998). This was observed by few farmers in Brong Ahafo region but generally observed by farmers in the Upper East region (Fig. 14).

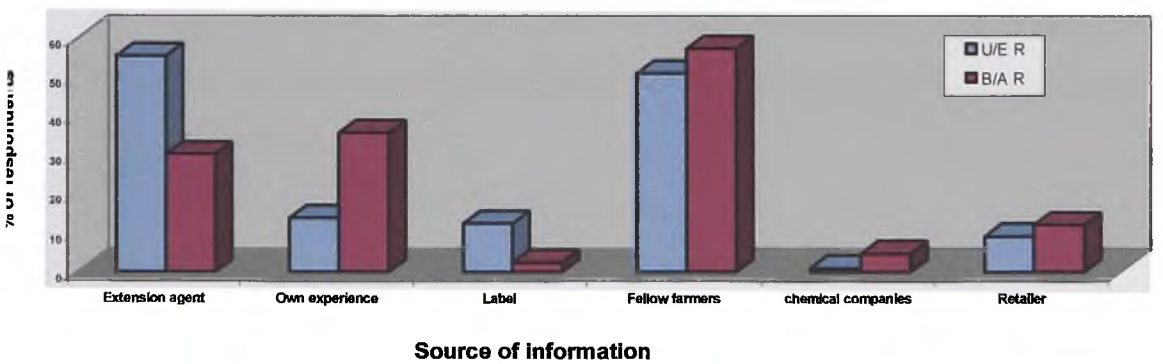

Fig. 15 Farmers source of information with regard to choice and use of pesticide products

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3.3.7.5 Source of information:

Tomato farmers were not well informed on correct use of pesticides. Only 55.3% and 35.7% of farmers had extension coverage on correct pesticide usage in the Upper East region and Brong Ahafo region, respectively (Fig. 15). This seemingly average coverage in the UER is partly due to the ICOUR extension network within the project area in the Upper East region, which provided professional advice to farmers in addition to agricultural extension agents of MOFA. Majority of farmers received expert advice from fellow farmers. Considering the high illiteracy rate among farmers, it is possible that advice on the usage of pesticide products may be incorrect, leading to abuse of pesticides.

3.3.7.6 Awareness of harmful effect of pesticides

Farmers showed greater awareness and knowledge about the toxic effect of pesticides on humans. This confirms FAO country report (1989), that incidence of pesticide poisoning that have been highlighted in the daily newspapers and on the radio have increase public awareness on the consequences of the mis-use of pesticides. However, knowledge about the problems of resistance due to the misuse of pesticides and effects on non-target organisms are very low. With regard to the perceived risk of insecticide residue in food, 23.1% and 23.9% from the Upper East region and Brong Ahafo region, respectively were very much aware of the problem.

3.3.7.7 Pesticide poisoning

Excessive use of pesticides without protective measures or regard for safety from contamination has given rise to increasing cases of poisoning of farmers. The 65 tomato growers interviewed in Upper East region had experienced various forms of poisoning

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symptoms. These included complaints of headache (4%), bodily pains (13%), dizziness (4%), itching /rashes (15%) soon after pesticide application. Similarly, in the Brong Ahafo region, 15.9% experienced irritation, 34.1% skin rashes and 22.7% body weakness. In general, incidence of direct poisoning is better known than the chronic effects of pesticides although neither form of poisoning is systematically reported.

3.3.7.8 Use of protective clothing

Since farmers do not generally perceive that pesticides can pose serious hazards during applications, precautions are usually not carefully followed during spraying operations. Partly because of the tropical conditions, many consider protective gear to be too hot to tolerate. Although most of the farmers have heard about the importance of the use of protective clothing, there is a high apathy towards its use (Table 16). At the Tano district in Brong Ahafo 30 out of 52 of the respondents did not use any protective clothing (Table 16). It is not surprising, therefore that the farmers have reported several incidences of pesticide poisoning during spraying. Farmers also cited high cost of protective clothing, and their non-availability as some of the reasons why they do not use them. These attitudes of farmers pre-dispose them to risk of insecticide poisoning "The New Developing World Disease" Anonymous, (1989).

3.3.7.9 Decision making in pesticide application

In the study, farmers were given three alternate questions on when and how they applied pesticides; individual decision (curative) based on the incidence of pests at certain threshold level, decision on an expert advice and decision based on calendar spraying. In the Brong Ahafo region, 100% of respondents sprayed their tomato crop based on calendar spraying at

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Table 16: Use of protective clothing during pesticide application.

[a]Type of Protective Clothing Used	Location/Production System			
	UER		BAR	
	Cases	%	Cases	%
Overcoat	10	17.9	3	5.8
Boots	32	57.1	12	23.1
Goggles	12	21.4	1	2
Respirators	15	26.8	3	5.8
Hand gloves	15	26.8	1	1.9
Hat	14	25.0	5	9.6
Long trousers	20	35.7	10	19.2
Long sleeves shorts	16	28.6	7	13.5
No clothing	5	8.9	30	57.7
No surveyed	56		52	

[a]multiple response

weekly or fortnightly intervals. However, 16 farmers out of 54 respondents did indicate that they monitor for pests levels but not as decision tool for pesticide application. Spraying in the Brong Ahafo region starts between 1 to 3 weeks after transplanting. Although the economic threshold concept serves as a basis for decision making in insect pest management, the determination of such thresholds has not been accomplished in most management programmes, with the result that very few research-based thresholds have been developed (Poston *et al.*, 1983). The number of insecticide applications may be reduced by spraying according to action threshold (Cartwright *et al.,* 1987). Some attempts have also been made to place pesticide usage on sound scientific basis by determining the critical time of

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application. The practicality of this approach need to be evaluated at various ecological zones and incorporated in 1PM programmes for the management of *Helicoverpa* in future.

3.3.7.10 Application rates and equipment

It was observed that application equipment differ under the two production systems. Most of the growers in the Upper East region (94.0%) used the manually operated knapsack sprayers fitted with the cone and deflector nozzles during pesticide application and only 6% of the farmers used the ultra low volume applications. On the contrary, 56.5% growers in the Brong Ahafo region preferred motorized mist blowers, otherwise recommended for the control of tree crop pests. Generally, deflector nozzles are used at low pressure for applying herbicides where large droplets and low drift are requirements. The use of this type of nozzle for insecticide and fungicide application will result in spray liquids mostly wasted, leading to environmental contaminations. Some ULV formulations were applied by farmers using motorized or knapsack applicators resulting in low coverage. If unskilled hands do the spraying, good amount of pesticides may be wasted.

The growers were able to give the various volumes of insecticide and quantities of fungicide used in a specified quantity of water. In the Brong Ahafo region tank mixtures are prepared in containers, which are larger than the tank of the knapsack sprayer for which dosage recommendation are based. Relating the doses to the recommended rates, indicated application of lower doses of pesticides. Application equipment were not calibrated before use and therefore spray volume and dose rates were not determined before spraying. Spray concentrations were considered generally high in the Upper East region. About 85.2% of farmers do not read the "Direction for use" on the label because they are in English and/or French instead of the local languages and because of the complexity of information.

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CHAPTER 4

4.0 DETERMINATION OF SELECTED INSECTICIDE RESIDUE LEVELS IN TOMATO *LYCOPERSICUM ESCULENTUM* MILL. IN SOME PRODUCTION AREAS IN GHANA.

4.1 Introduction

In Ghana, vegetable farmers use excessive amounts of sometimes highly persistent pesticides on their crops because of lack of knowledge and the increasing cost of the recommended pesticides (NARP, 1997). Not only are the doses very high but farmers also spray at very short intervals (Brempong-Yeboah, 1992; NARP, 1993; 1997; Critchley, 1997; Ninsin, 1997). These practices are largely governed by attempts by farmers to produce clean unblemished fruits because of enormous pressure exerted by distributors and consumers.

The problem is further compounded by the proliferation of wide range of pesticides in the Ghanaian market, which include some restricted pesticides such as Endosulfan and Lindane recommended for cotton and cocoa pests control, respectively (FAO, 1989; 1990; NARP, 1997; Yeboah, 1998; Gerken *et al.*, 2000). The relatively low cost of the organochlorines, easy access and versatility in action against various vegetable insect pests account for their increasing use on vegetables. However, the organochlorine pesticides are persistent in the environment and bio-accumulate along food chains (Mbakaya *et al.*, 1994).

Since these chemicals are potentially toxic and highly persistent, there is a pressing need for their control and monitoring in the environment. Monitoring pesticide usage and contamination in food commodities provides useful information on assessing food safety to consumers.

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The objective of the study thus, was to determine residue levels of Lindane, Endosulfan and Chlorpyrifos insecticides in harvested tomato fruits and compare with WHO/FAO Maximum Residue Limits (MRL's).

4.2 Materials and methods

4.2.1. Chemicals and reagents.

i). Ethyl acetate and Cyclohexane were analytical grade and obtained from Fluka Chemie G, Industriestrasse 25, CH-9470 Buchs, Switzerland.

ii). Methanol, 99.8% was analytical grade obtained from R. P. Normapur, Prolabo 12, rue Pelee 75011, Paris.

iii). N-hexane, 99%+ (Capillary G. C) were analytical grade obtained from Sigma Chemical Compamy, P. O. Box 14508 S. T. Louis, M 0 63178, U.S.A.

iv) Acetone and anhydrous sodium sulphate (Na_2S04) of analytical grade were obtained from Merck KGaA, D-64271 Darmstadt, Frankfurterstrasse 250, Germany.

Pesticide Standards: Endosulfan, Lindane and Chlorpyrifos insecticide standards were purchased from DR. Ehrenstorfer Gmbh, Ausberg, Federal Republic of Germany; and had purity ranging from 98.2% to 99.5%.

4.2.2. Preparation of standard solutions.

Stock solution of pesticide reference standards of all active ingredients were prepared from certified reference materials. Primary stock solution of all active ingredients used in this study were initially prepared at 1.0 mg / mL by dissolving approximately 0.05 g pure pesticide (corrected for purity of the reference standard, e.g.: for % purity of 98.5, 0.05 x 100/98.5 g was weighed) in 50 mL hexane.

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Dilution of the stock solutions was carried out to prepare the necessary intermediate stock solutions and then serially diluted to produce a series of working standard solutions of appropriate concentrations ranging from 0.01 µg / ml to 1.0 µg / mg.

4.2.3. Apparatus

(i) SPE Bond Elute C-18 and Micro syringes (10 µL) with needle (Hamilton) were obtained from Supelco Inc., Sulpelco park, Bellefonte, PA. 16823-3441 U.S.A.

(ii) Ultra Turrax high-speed mixer

(iii) Rotary evaporator

4.2.4. Cleaning of glassware

All the glassware were thoroughly washed with a brush in hot water and detergent. They were rinsed five times with tap water, twice with distilled water and allowed to dry. They were again rinsed with acetone. The glassware were placed overnight in an oven at 300 °C and cleaned immediately with hexane before use.

4.2.5. Sampling locations

Tomato fields treated with Endosulfan, Lindane and Chlorpyrifos insecticides by farmers were selected. Samples of tomato fruits were randomly taken during harvest from Derma and Techimentia in the Tano district of the Brong Ahafo region and Tono and Vea irrigation areas in the Kassena Nankani and Bolgatanga districts of the Upper East region (Fig. 16) between April and July 2000. The samples were analysed to determine residue levels of selected insecticides.

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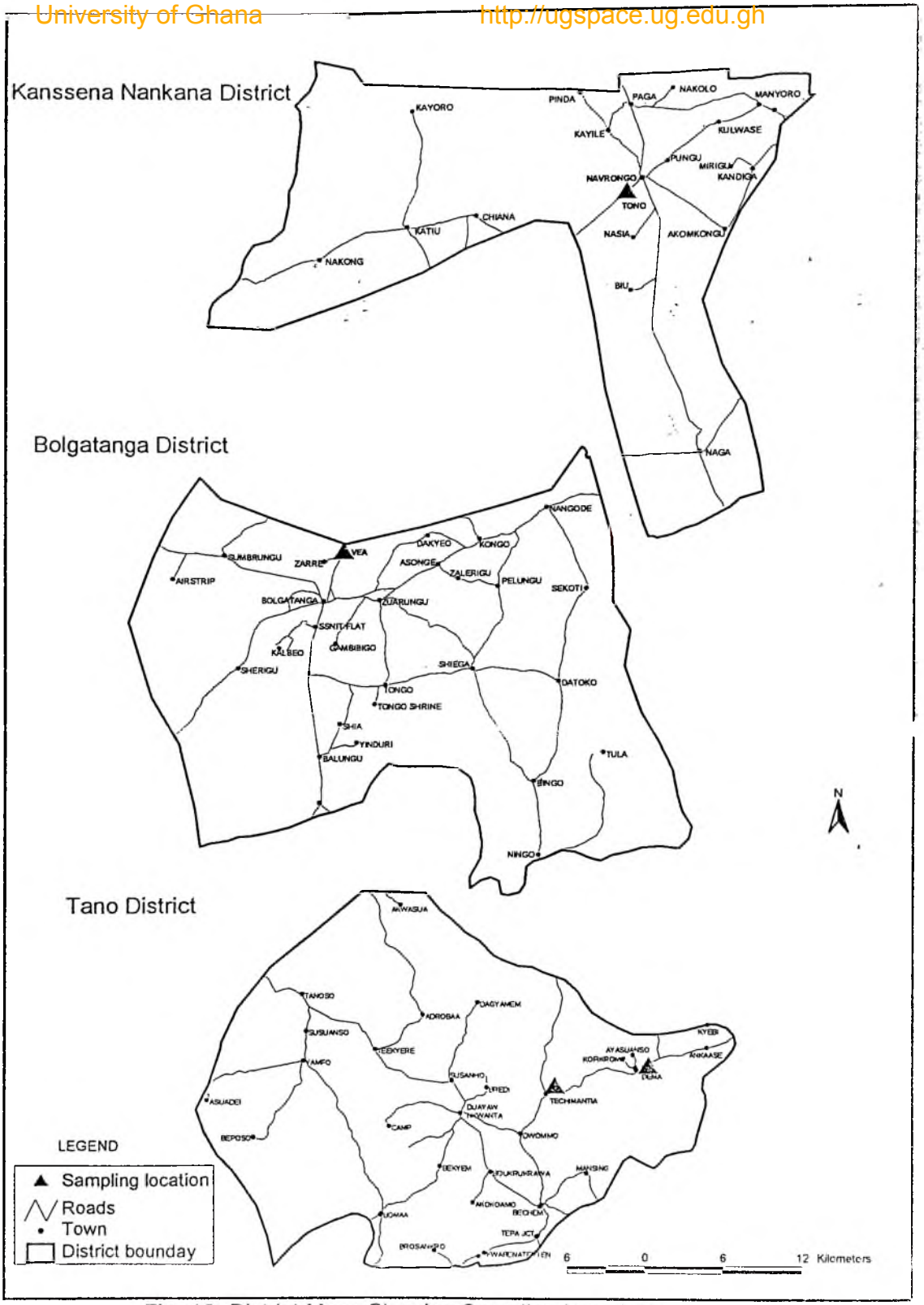

Fig. 16 District Maps Showing Sampling Locations

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4.2.6. Sampling procedure

The fields to be sampled were divided into four sections. A random sample of about 10 fruits from each of the sections was taken and bulked to form one composite sample. These samples were collected and wrapped in aluminium foil, transferred into clean polyethylene bags and transported to the laboratory and frozen until extraction. Information on details of insecticides and their active ingredients of interest analysed in tomato fruits for their residue levels are indicated in table 16.

4.2.7. Sample analysis.

4.2.7.1. Extraction of residues from samples

Before extraction, each sample was allowed to thaw to equilibrium. Five hundred grammes (500 g) sample of tomato fruits was placed on a pre-cleaned plate. Fruits were chopped with clean kitchen knife and thoroughly mixed together. Ethyl acetate extraction method described by Anderson and Palsheden (1991) was used. An aliquot of 75 g of sample was taken and placed in a 500 ml glass jar and homogenised for two – three minutes by Ultra-Turrax high speed mixer with 200 ml ethyl acetate solvent and 40 g anhydrous sodium sulphate (Na_2S04). The sodium sulphate was oven dried at 550 °C for two hours before it was used. The filtrate was decanted through a funnel with a glass wool and 20 g Na_2S0_4 was added to the stem. Hundred millilitre (100 mL) aliquot of ethylacetate layer was taken, concentrated to dryness in a rotating film evaporator and redissolved in 5 ml ethyl acetate/ cyclohexane (1:1) (V:V).

4.2.7.2. Clean up procedure of extracts

A solid phase extraction (SPE) column fitted with C - 18 catridge was pre-conditioned by flushing two - 10 ml volumes of methanol followed by two - 10 ml volumes of distilled water through the column. One ml of extract, which is equivalent to 7.5 g of biological

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sample, was taken and dried over Nitrogen. The residue was redissolved in 1 ml ethyl acetate and diluted with water to 2.5 ml. The aqueous extract was passed through SPE column at flow rate of 2 ml / min. The column was washed with 1 ml distilled water. The washed column was vacuum dried for 15 minutes. The analytes trapped in the column were eluted with 1.5 ml of hexane into a glass vial, made up to 2 ml with hexane and analysed by GC.

Table 17. Organophosphorus and organochlorine insecticides analysed to determine their residue levels in tomato fruits.

No	Treatment history (Product name)	Active ingredient (a. i.)	Chemical group	No of samples analysed
1.	Thiodan 50 EC, Thionex 35 EC/ULV)	*Endosulfan*	Organochlorine (OC)	8
2.	Gammalin (Gamma BHC)	*Lindane*	Organochlorine (OC)	10
3.	Dursban 4E	*Chlorpyrifos*	Organophosphorus (OP)	8

4.2.7.3. Gas Chromatographic analysis

A gas chromatograph (Hewlett Packard 5890 series II) with integrator (Hewlett Packard 3396A) was used for analysis of Lindane, Endosulfan and Chlorpyrifos insecticides. A capillary column (length 30 m, ID 0.53 mm film thickness 1.5 mm) coated with DB-5 was used for the analysis. The working conditions were: oven temperature 150 °C; injector temperature 150 °C; detector temperature 250 °C and carrier gas flow 20 ml N_2 / min. The conditions for alpha and βeta Endosulfan analysis were slightly varied as; oven temperature 200 °C; injector and detector temperature 250 °C. Integrator operations were as follows; Chart speed (0.5), attenuation (4), threshold (2) and peak width (0.4). Sample peaks were identified by their retention times compared to

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the corresponding retention times of the insecticide standards (Figs 17 and 18). No independent method of confirmation was applied.

4.2.7.4. Calculation of residue levels

Residues levels were calculated using the equation (NRI, 1994) below:

$$\text{Residue level} = \frac{\text{Concentration in final extract x dilution factor}}{\text{Weight of sample analysed}}$$

4.3 Results and discussion

Tomato fruits from farmers' fields reportedly sprayed with Lindane, Endosulfan and Chlorpyrifos insecticides showed varying levels of fruit contaminations in some samples analysed. Fruits sampled at harvesting from the Tano district of the Brong Ahafo region had Lindane residues ranging from 0.005 mg/kg to 0.712 mg/kg (Table 20). All the 10 samples analysed were found to contain residues of Lindane insecticide. However, the levels were generally low and below the Maximum Residue Limits (MRL's) of 2 mg / kg check (FAO, 1993). The Tano district is a cocoa producing area and Lindane is a recommended pesticide sold in the district at a subsidised price for the control of cocoa capsids. The levels detected could be attributed to more intensive use of the pesticide to improve cocoa production and quality in the area that may have contaminated the fruits. There was evidence of usage of Lindane by few farmers for tomato production as a substitute to the recommended insecticides. With the present escalating cost of agro-chemicals in the country, few farmers can afford to buy the recommended pesticides.

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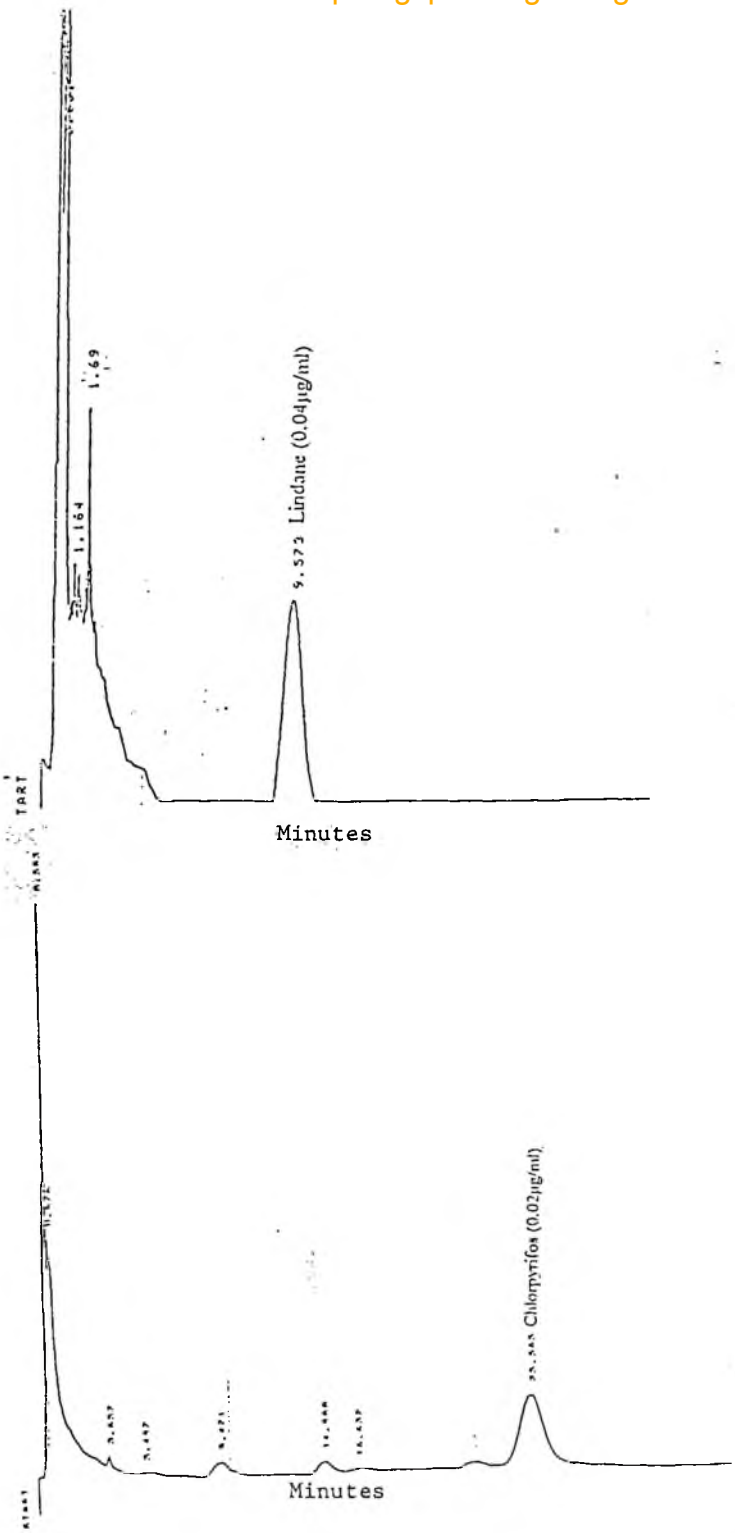

Fig. 17: Chromatograms of Lindane and Chlorpyrifos standards.
Conditions: Oven temperature 150°C; injector temperature 150°C; detector temperature 250°C ECD; Carrier 2 ml/min.; injector volume 1 ml, direct.

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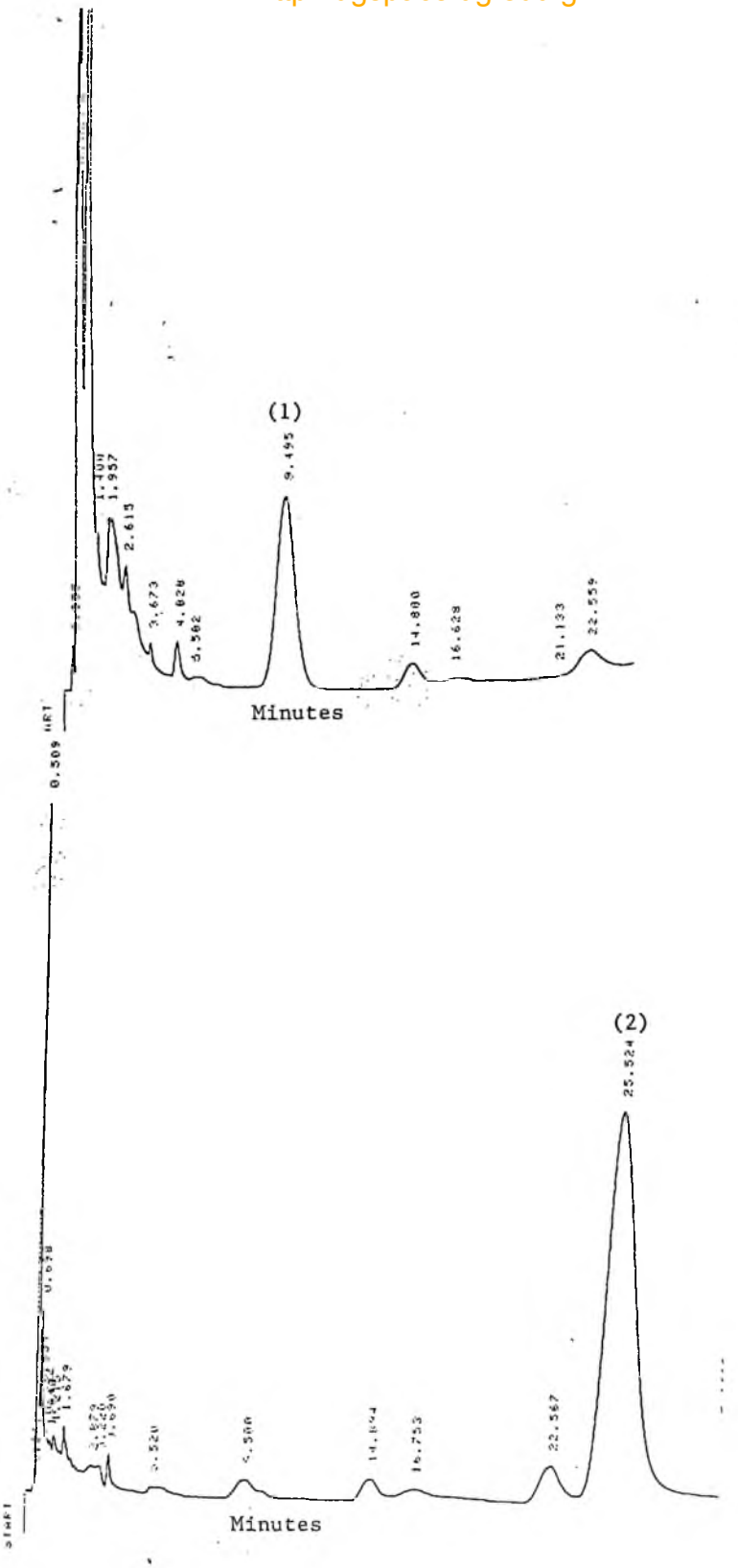

Fig. 18: Chromatograms of Lindane and Chlorpyrifos insecticide in tomato samples: (1) Lindane; (2) Chlorpyrifos

Conditions: Oven temperature 150°C; injector temperature 150°C; e 250°C ECD; Carrier 2 ml/min.; injector volume 1 µL

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Vegetable farmers might intentionally buy cheaper insecticide like lindane or the wrong equipment may be used in Brong Ahafo regions; thus accounting for the contamination.

Table 18: Mean residue levels of lindane insecticide in tomato fruits in the Tano District of the Brong Ahafo region (mg /kg fresh weight)

Samples	Residue levels (mg/kg)	FAO/WHO MRL'S (mg / kg) for Lindane FAO/WHO 1993	ADI (mg /kg) for Lindane FAO/WHO, 1993
1	0.712	2	0.008 mg / kg body weight (1991)
2	0.380	"	
3	0.021	"	
4	0.012	"	
5	0.012	"	
6	0.005	"	
7	0.003	"	
8	0.006	"	
9	0.422	"	
10	0.266	"	
Mean	0.184		
SD	0.248		
CV(%)	132.60		

ADI =Acceptable daily intake.

Majority of tomato farmers from Tano district in the Brong Ahafo region used Endosulfan, which is restricted for cotton production in Ghana. All the eight samples analysed from field supposedly sprayed with Endosulfan were found to contain residues of alpha Endosulfan ranging from 0.014 mg /kg to 0.126 mg / kg (Table 21). βeta Endosulfan was found to be below detectable limits of 0. 001 mg / kg in all samples analysed.

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Generally, farmers spray at very low concentrations. The detected residues may be attributed to the high frequency of application, persistency of chemical products and short pre-harvest intervals generally observed by tomato farmers in the Brong-Ahafo region of Ghana. There were greater variations in residue levels among the samples collected from different farms. This is probably because farmers do not follow recommended practices as evident in findings (Personal Survey). Application rates, frequency and timing were mostly based on individual assessment on the need for pesticide application without expert advice.

Table 19: Mean residue levels of Endosulfan (Alpha plus βeta) in tomato fruits collected from Tano district of the Brong Ahafo region (mg /kg fresh weight)

Sample	Residue Levels mg / kg		FAO/WHO MRL's mg / kg for Endosulfan, 1993	ADI (mg / kg) for Endosulfan[a] FAO, 1993
	α	β		
1	0.044	BDL	2.0[a]	0.006mg / kg body weight (1989).
2	0.028	BDL	"	
3	0.054	BDL	"	
4	0.025	BDL	"	
5	0.014	BDL	"	
6	0.020	BDL	"	
7	0.019	BDL	"	
8	0.126	BDL	"	
Mean	0.041			
SD	0.037			
CV(%)	90.20			

a = sum of alpha – and beta - endosulfan and endosulfan sulphate.
BDL; Below Detectable Limits at 0.001 mg / kg for beta endosulfan.

A common practice was buying and storing small quantities of pesticides in containers other than the original ones. Most farmers also use motorised mist blower spraying

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machines previously used for capsid control in cocoa plantations with the restricted insecticides such as Lindane and Propoxur. If these equipments and containers are not thoroughly washed, previous pesticides used may be a source of contamination and can be a possible source of residues detected in some samples.

Table 20: Mean residue levels of Chlorpyrifos on harvested tomato fruits from Tono & Vea irrigation project areas in the Upper East Region (mg / kg fresh weight)

Sample	Residue levels (mg / kg)	FAO /WHO MRL's (mg / kg) for Chlorpyrifos	ADI (mg / kg) body weight for Chlorpyrifos (FAO/WHO) 1982
1	0.613	0.5	0.01 mg / kg body weight (1981).
2	0.381	"	
3	0.485	"	
4	0.370	"	
5	0.082	"	
6	0.937	"	
7	0.166	"	
8	0.019	"	
Mean	0.381		
S. D.	0.280		
CV(%)	73.70		

In the Tono and Vea irrigation areas of the Upper East region of Ghana, residues of Chlorpyrifos, a widely used organophosphorus insecticide, were detected on harvested tomato fruits for the market. All the eight samples analysed had residues which ranged from 0.019 mg / kg to 0.937 mg / kg (Table 19). In all, 25% of samples analysed had residue levels exceeding FAO/WHO MRL's check of 0.5 mg / kg (FAO/WHO, 1993). According to Oudedjan (1994), residue levels in food depend on factors, which include concentration of chemicals, timing of applications and whether or not the edible part of the crop is exposed to the chemical treatment. Since the edible parts of the tomato crop

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are always exposed, frequent insecticide application will lead to the build up of residues of pesticides at the time of harvest. The most likely source of significant levels of insecticide residues in food is application of pesticides immediately before harvest, which is a common practice in the areas investigated. Most vegetable farmers apply pesticides just at the time of harvesting because some traders insist on seeing traces of pesticides on the harvested fruits to prolong shelf life (Personal interview). Considering the tender testa of the tomato fruits, one could just imagine the health risk being posed by the continuous use of these pesticides in tomato production and the fact that the fruit is sometimes consumed fresh.

The higher levels of chlorpyrifos residues in the Upper East region may be attributed to higher concentrations of insecticides applied. In the southern and middle belt of Ghana, frequent rainfall and surface irrigation sometimes wash surface pesticides and reduces the levels on the plant. This probably explains why the residue levels were quite low in the forest region. On the contrary, tomato production in the Upper East region is predominantly under irrigation. There is no rainfall and pesticides applied are hardly washed off by rainwater except degradation by environmental factors.

The analysis also revealed that 25% of the samples treated with chlorpyrifos insecticide had residue exceeding FAO/WHO MRL's. The principle of MRL's is that, if a pesticide is used as recommended, following good agricultural practice (GAP), residue levels on crop at the marketable stage should not exceed the MRL's value.

According to Oudedjan (1994), GAP in the use of pesticides with the aim of minimizing noxious effects on humans, animals and the environment include:

Choosing the least toxic and least persistent pesticides that will control pests in the field and storage. As a general rule, persistent and/or cumulative pesticide

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Table 21: Analysis of samples of tomato fruits containing insecticide residues from Tano district (BAR) and Tono &Vea (UER).

Insecticide	Location	No. of samples analysed	No. of samples with detectable residues	% of detectable samples with residues	Mean Residue level (mg / kg)	S.D
Lindane	Derma &Techimentia	10	10	100%	0.18 (0.01 - 0.71)	0.25
Endosulfan – alpha	"	8	8	100%	0.04 (0.01 - 0.12)	0.037
Endosulfan – beta	"	8	n. d	n. d	n. d	-
Chlorpyrifos	Tono & Vea	8	8	100%	0.38 (0.02 – 0.94)	0.28

n. d: not detected; S.D: Standard deviation; Range in Brackets.

should not be used on fodder crops.

- Applying on the target area only the minimum amount of pesticide required while determining the number of treatments on a need basis in relation to actual pest infestation.
- Choosing a formulation, which combines maximum efficiency of the selected pesticides with minimum risk.

  Selecting the method of application, which offers optimum control with minimum contamination of crops and the treatment in relation to vulnerable stages of the pest's development.
- The interval between last application and harvest should be as long as possible in order to permit the greatest reduction in pesticide residues.
- Crop rotation should be adjusted in such a manner that residues in the edible parts of a crop, as a result of previous treatments will be minimised.

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The use of Lindane and Endosulfan (organochlorines) in vegetable production violates the basic fundamental guideline of GAP outlined above. These are restricted insecticides and in accordance with commonly recognised practice in the absence of additional regulatory restrictions, the use these pesticides may cause unreasonable adverse effect on people, animals, crops or on the environment (Pesticide Management and Control; Act 528, 1996). By regulation and registration, Lindane is restricted for the control of cocoa capsids (NARP, 1993; Yeboah, 1998 and Gerken *et al.*, 2000).

If their use in agriculture and food production cannot be discontinued, then it must be regulated with emphasis on good agricultural practices as any careless mishandling or wrong application could lead to serious deleterious health effects in human and the environment. Measures need to be adopted for an improved practice of pesticide use, increased monitoring and improved advice to farmers to reduce potential residues of pesticide on agricultural products.

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CHAPTER 5

GENERAL DISCUSSION AND CONCLUSION

Among the insect pests attacking tomato, there was considerable knowledge of *Heliothis* damage by farmers. This is because this insect pest occur more frequently, easily apparent in the field and their damage are clearly distinguished (Critchley, 1997). This pest problem has also increased with increasing diversification of crops and increasing areas under cropping, resulting in availability of crop hosts over large areas.

In the Upper East region, crop rotation was limited only within the year where tomato fields were cropped with soyabeans, groundnuts, sorghum and other staples in the rainy season. Tomato is often cropped on same land during the dry season. The continuous cropping on same land and use of monoculture continue to provide favourable feeding opportunities for insects. Since most insect pests tend to be restricted or associated with crop plants of one family, the adoption of crop rotation measures may have greatly reduced population of such pests species that seek to oviposite on the crop the previous cropping season. The role of cultural practices, plant resistance and crop rotation in producing "healthy" vegetables as the base for integrated vegetable management has always been highlighted (Baudoin, 1994). In the forest region, where rotation and fallowing of tomato fields were practiced, small-scale farmers need to be educated and encouraged to rotate host and non-host plants which often provides an effective and economical means of reducing pest population to sub-economic levels.

Farmers' source of tomato seeds in the Brong-Ahafo region leaves much to be desired. Approximately 100% of the farmers interviewed obtained seeds from previous years harvest

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or friends. The unscientific method of seed selection and extraction may easily lead to contamination by nematodes, fungi, bacteria and viruses because of the high percentage of plants that are likely to be infested. The preventive and curative measures of applying seed treatment chemicals on seeds in storage and before nursing were not practiced. The use of effective seed treatment chemicals that will control a number of pests and diseases constitutes an active area of research. This is because it is normally easier and more effective to reduce or eliminate pathogens from seed stock than controlling diseases spread after sowing.

Under both production systems, the use of inorganic fertilizers to increase crop productivity was common. A balance nutrition of N P K and the micro elements is very important in minimizing plant stress, susceptibility to pests and in maintaining plant health (El-Zik & Frisbie 1985). Organic fertilizers were not applied in tomato production. Commercial tomato farmers could be encouraged to exploit the possibility of incorporating the use of organic source of plant nutrients such as organic manure and composting into their cropping system. Since a given fertilizer form and/or dosage may favour certain groups of pests and at the same time discourage other parasites, research in the use of organic/inorganic fertilizers and assessment of pest levels in tomato farming systems may provide an alternative IPM strategy for increased crop productivity.

To protect their investments, the control of *Heliothis* and other pest of tomato relies heavily on the use of pesticides which dependency has a potential longer term problem of pest

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resistance. Under the two production systems, there were cases of pesticide abuse at the field level and lack of adequate control over the way pesticide were applied. Because of the use of wrong application equipment in some instances and low quality of some of the spraying equipment, lack of spare parts and poor service and repairs facilities in the farming zones, condition of sprayers in the field was unsatisfactory. This situation combined with the general lack of understanding on the part of farmers and extension workers on how to choose and use sprayer safely and efficiently paints a worrying picture. If pesticides are to be used within effective IPM and sustainable vegetable production systems a clear requirement is safe and efficient pesticide application equipment. Where such equipment is available and is used in a rational and responsible way, pesticide can play a valuable role in the quest for safe and cost-effective increases in food production. There is an urgent need to teach farmers safe practices to particularly focus on the equipment used to apply pesticides

Majority of farmers had to rely on fellow farmers and pesticide retailers/agents for advice on the choice and use of pesticide products in the control of pests of tomato. Advice on the insecticide(s) use therefore had no scientific basis. In view of the perceived low efficacy of the single formulated active ingredients, majority of farmers in the Brong-Ahafo have resulted in the use of insecticide mixtures, which is contrary to the principles of pesticide management. This same situation has resulted in the use of highly concentrated insecticides such as Deltaphos 262 EC (*Deltamethrin + Triazophos*), Polythrin C 336 EC (*Cypermethrin + Chlorpyrifos methyl*), Cypercal P 183 EC (*Cypermethrin + Profenofos*) and Baythroid P 168 EC (*Cyfluthrin + profenofos*), which are not registered and/or approved for use on vegetables in Ghana. Additionally, the labels on these insecticides do not adequately inform users on the proper handling and use of these chemicals. Most of these labels are in French

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for which extension agents and farmers do not understand. These insecticides are applied more frequently and at short intervals without the consideration of threshold levels. The 'blanket' approach that growers pre - emptively spray pesticides regardless of the particular pest problems must be considered as economically wrong and ecologically alarming. A major barrier in farmers' ability to adopt a more

integrated pest management approach is the shortfall of information and the understanding in the key areas like:

- the recognition of certain types of pest and disease and their economic significance,
- appropriate pesticides for different pests problems and suitable application regimes and
- health, safety and environmental issues (Yvon, 1997).

Thresholds above which spraying provides economic benefit have been estimated for most susceptible crops and applied generally in high value crops with low damage tolerance. Use of sampling and application of thresholds has been associated with a reduction in the average number of insecticide application per cotton crop from 15-18 in the late 70's to 10-12 (Fitt 1994). A reduction in number of insecticide sprays from nine in 1979/80 to four/five in 1995/96 using new ETL's was reported in Sudan (Abdelrahman *et al.,* 1997). Similar reduction may be possible in tomato by placing pesticide usage on sound scientific basis by determining the critical time of application. However, many farmers still want crops totally free of insects by choosing the security provided by chemicals rather than risking yield loss especially when market prices are very high.

Consequently, fields sampled for residue analysis revealed quite significant levels of Chlorpyrifos and restricted organochlorines residue levels in tomato fruits in some

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production areas of Ghana. Lindane, Chlorpyrifos and Alpha endosulfan were detected in all the samples analyzed. βeta endosulfan was below limits of detection at 0.001mg/kg. The average residue levels were generally low and none were above the maximum residue limits for the organochlorines. However, 25% Chlorpyrifos samples exceeded FAO/WHO MRL's values of 0.5 mg / kg. The dosages applied were possibly higher than recommended and it is likely that the degradable pattern of the insecticides were not taken into consideration. Some samples indicated other unidentified peaks on the Chromatograms (Fig 18). It is possible that other pesticides and their metabolites were present, but could not be identified and quantified because of lack of appropriate standards.

Though, the levels of the organochlorines were generally low, appreciable build up of residues with time may occur because of the continuous use of these restricted and persistent pesticides in the growing areas. If their use in agriculture and food production cannot be discontinued, then it must be regulated with emphasis on Good Agricultural Practice and adoption of IPM programme as any careless mishandling or wrong application could lead to serious deleterious health effects in human and the environment.

The use of alternative control options and other biological pesticides such as *Bacillus thuringiensis* (Bt) formulations and botanicals were insignificant though these have been recommended in integrated pest management practices. Most tomato farmers probably, are unaware of the correct use of these environmentally friendly insecticides.

Integrated Pest Management (IPM) programme begin with examining traditional cropping systems and pest management strategies. Baseline information is therefore a primary component for which this study has sufficiently sought to provide. The study has shown that farmers do not practice IPM. Highly hazardous insecticides recommended for the control of cocoa and cotton pests were used on tomatoes. Also, persistent organochlorines were among

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insecticides used by farmers for the control of pest in the major tomato growing areas in the Brong Ahafo and the Upper East region of Ghana. This confirms speculation and concerns of many that hazardous chemicals are still being used on food crops in Ghana.

Most of the tomato farmers were not well informed on safe use of pesticides and applied pesticides incorrectly, more frequently on calendar spraying, thus polluting the environment and contaminating food crops. About 25% of tomato samples had residue levels exceeding the FAO/WHO MRL's for Chlorpyrifos. The fact that there were "quite significant levels" of residues of Lindane and Endosulfan that are not even recommended for use in vegetables is a cause for concern.

The findings from this research underscore the need for Ghana to develop the capacity and capabilities for routine monitoring of residue levels to ensure food safety. Concerted efforts, therefore, must be devoted immediately to develop practical and justifiable IPM packages for implementation, advocating the minimal use of pesticide compounds in tomato production in the major production regions of Ghana.

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CHAPTER 6

RECOMMENDATIONS

1. Tomato farmers must be helped to control the insect pests without compromising human health, while assuring them of optimum yield and their income. To achieve this, pesticide companies must collaborate with researchers to educate growers to be able to make informed choices with respect to choice of insecticide in controlling tomato pest. This recommendation should be based on sound scientific basis on efficacy of the product and critical time of applications.

2. The MOFA will have to strengthen extension delivery service so that education on safe and efficient use of pesticide is intensified. Education and training in methods of application and application hygiene should be stressed.

3. The Environmental Protection Agency of Ghana and Plant Protection and Regulatory Services of MOFA must stand to the task of enforcing the relevant sections of the Pesticide Control and Management Act (528) to rid the market of pesticides not registered for use and enforce all laws and regulations that with ensure sound pesticide management in Ghana.

4. A monitoring programme for relevant pesticides in foods should be developed, considering the local pesticide use patterns of farmers and prevailing climatic conditions.

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Monitoring should include the estimation of total pesticide use as well as the occurrence of pesticide-induced illness or death.

5. Research should be undertaken to develop or validate analytical techniques for pesticide residue analysis especially those techniques that are simple, rapid and useful in monitoring and surveillance of pesticide residue programmes on food and water. Pesticide use patterns and residues on other crops especially vegetables and fruits on farm and in the market should be investigated to ascertain their residue status.

6. The Plant Protection and Regulatory Service Directorate of Ministry of Food and Agriculture is currently, advocating the adoption of IPM as a strategy for pest control. There is the need for refining, upgrading, and expanding in research, curriculum development and validations at all levels from time to time to adjust to changing pest problems, available new pest control technologies and the changing economic situation. Priority should be given to vegetable IPM programmes in view of pesticide mis-use in vegetables and possible human risk.

7. In view of the perceived low efficacy of some of the recommended insecticides for the control of key pests of tomatoes, there is the need to initiate resistance monitoring studies as a basis for recommending appropriate resistance management strategies for sustainable pest management in tomato production.

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APPENDICES

APPENDIX A

Nutritional content of tomato fruits per 100g weight (Tayie & Lartey 1999)

Nutrient	Content
Water	94g
Protein\Fat	1.0g
Fat	0.1g
CH_{20}	4.0g
Ca	5mg
Fe	0.4mg
Vit A	250ug
Vit B_1	0.02mg
Vit B_2	0.05mg
Niacin	2mg
Vit C	15mg

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APPENDIX B.

AFRICAN REGIONAL POST GRADUATE PROGRAMME IN INSECT SCIENCE (ARPPIS), UNIVERSITY OF GHANA, LEGON

Questionnaire to assess farmers' knowledge on insect pests problems, cropping practices and pesticide use patterns in tomato *Lycopersicum esculentum* Mill in some selected production systems in Ghana

(Please either fill in the blank space provided or tick where applicable)

A. PERSONAL DATA.

1. Name of farmer (optional) .....

2. Area/Location of farm .....

3. Sex of respondent ☐ Male ☐ Female

4. Age

☐ 15-20 ☐ 41-50

☐ 21-30 ☐ 51-60

☐ 31-40 ☐ 61-70

5. What is your educational level?

☐ No school
☐ Middle school
☐ J.S.S.
☐ SS Level
☐ 'O' Level
☐ 'A' Level
☐ Tertiary Level
☐ Non formal

6. How many years have you been cultivating tomato? .....

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B CROPPING SYSTEM AND AGRONOMIC PRACTICES.

7. Why do you prefer to cultivate this vegetable crop? .....

8. What variety do you grow? .....

9. Why do you prefer this variety? .....

10. What is the area cultivated for tomato this season?

- ☐ Less than 1 acre
- ☐ 1-2 acre
- ☐ 2-3 acres
- ☐ 3-4 acres
- ☐ 5 and above
- ☐ Others (specify)

11. Do you crop on the same plot every year?

☐ Yes ☐ No

12. If yes, how many times do you continuously crop on the same plot?

- ☐ Two times
- ☐ Three times
- ☐ Four times
- ☐ Five times
- ☐ Ten or more
- ☐ Others (specify).....

.....

13. What period of the year do you crop?

- ☐ Rainy season
- ☐ Dry season
- ☐ Both season

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14. How many times in a year do you crop tomato?

- ☐ Once
- ☐ Twice
- ☐ Three times
- ☐ Four times

15. What is the source of water for cultivation?

- ☐ Rainfall
- ☐ Dams/Dugouts
- ☐ Rivers
- ☐ Others (specify).....

.....

16. How often do you apply water or irrigate your farm?

- ☐ Once a day
- ☐ Once every 3 days
- ☐ Every 5 days
- ☐ Every 7 days intervals

17. What is the source of your seeds?

- ☐ Previous years harvest
- ☐ Friends
- ☐ Registered seed retailers
- ☐ Others (specify).....

.....

18. Did you plant your tomatoes this season?

- ☐ Direct Seeding
- ☐ Nursery

19. How long do seedlings stay in the nursery?

- ☐ 2 weeks
- ☐ 3 weeks
- ☐ 4 weeks
- ☐ 5 weeks and more

20. Do you grow a sole tomato crop or you or you interplant with other plants (please elaborate)

.....

.....

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.....

21. How is planting done?

- ☐ On the Flat
- ☐ On the ridges
- ☐ Others(specify).....

.....

22. Do you apply fertilizer(s) ☐ Yes ☐ No

23. If yes, what type do you apply?

- ☐ Inorganic
- ☐ Organic
- ☐ Both

24. Please indicate the name of inorganic fertilizer if any? (more than *one* answer is possible)

- ☐ 15-15-15
- ☐ 23-15-15
- ☐ 20-20-0
- ☐ Urea
- ☐ Ammonium sulphate
- ☐ Others (specify).....

.....

.....

25. Elaborate on how and when you apply fertilizer(s)

.....

.....

C KNOWLEDGE OF INSECT PEST PROBLEMS.

26. Do you experience insect pest attack on your tomato crop? ☐ Yes ☐ No

27. Can you identify them? ☐ Yes ☐ No

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28. If yes, describe or name the major insect pests in order of economic importance and damage.

Pest	Kind of damage
(1).....	.....
(2).....	.....
(3).....	.....
(4).....	.....
(5).....	.....
(6).....	.....
(7) Others (specify).....	.....
.....	.....

29. Which is the most infested crop stage
(rank as 1st, 2nd, 3rd etc. against the crop stage)

- ☐ Nursery/Seedling
- ☐ Seedling
- ☐ Vegetable
- ☐ Flowering
- ☐ Fruiting

30. Indicate the major insect(s) against the various crop stages?

	Stage of Crop	Insect causing damage
i.	Nursery/Seedlings	.....
ii.	Vegetative	.....
iii.	Flowering	.....
iv.	Fruiting	.....
v.	Others	.....

(Please indicate the key pests against the crop part they attack)

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31. Do you control the insect pests on your crop? ☐ Yes ☐ No

32. If yes, what principal method of control do you use? *(More than one answer is possible)*

☐ Physical
☐ Cultural
☐ Biological
☐ Chemical
☐ Traditional (specify).....
.....
.....

33. Why do you use or prefer these/method(s)?
.....
.....
.....

34. Do you use other control methods/measures in addition to the principal method to control insect pests on tomato crop? ☐ Yes ☐ No

35. If yes, name them or elaborate
.....
.....
.....

36. Do you monitor pest population as decision tool for pest control? ☐ Yes ☐ No

37. Do you wait for insect attack before control? ☐ Yes ☐ No

38. If yes, at what pest population or damage levels do you take decision to control them?
.....
.....
.....

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39. How do you take the decision to control these pest(s)?

- ☐ Prophylactic use (calendar spray)
- ☐ Depending on intensity (curative)
- ☐ After expert advice
- ☐ Others (elaborate)

.....

.....

40. If no, at what stage of the crop do you start controlling the pest and why?

.....

.....

.....

41. Do you experience crop damage if no control is applied?

☐ Yes..... ☐ No..

42. What is the average % damage or loss you experience if no control is applied?

- ☐ up to 50%
- ☐ up to 60%
- ☐ up to 70%
- ☐ up to 80%
- ☐ up to 90%
- ☐ up to 100%

43. After harvest, what is the average % loss of damage fruits if adequate control measures are applied?

- ☐ up to 5%
- ☐ up to 10%
- ☐ up to 20%
- ☐ up to 30%
- ☐ up to 40%
- ☐ up to 50%

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☐ 50 and above

44. In your opinion, why do you still experience losses after routine chemical treatment against insect pests?

.....

.....

.....

45. What is your opinion about the efficiency of chemical treatment against insect pest?

☐ efficient in controlling all pest

☐ Control only some pests

☐ Others (specify)

.....

46. Indicate insect pests of which chemical insecticides do not well control if any?

(i).....

(ii).....

(iii).....

(iv) Others specify.....

.....

E DISEASE PROBLEMS.

47. Do you experience disease incidence on your crop? ☐ Yes ☐ No

48. Can you identify the major diseases? ☐ Yes ☐ No

49. If yes, please rank the diseases in order of economic importance?

.....

.....

.....

.....

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50. Which is the most infected crop stage? (rank as 1st, 2nd or 3rd etc/ against the crop stage.)

(1) Nursery/seedling
(2) Vegetative
(3) Flowering
(4) Fruiting

51. Indicate the major diseases against the various crop stages

Stage	Disease/Symptoms
(i) Nursery/seedling	.....
(ii) Vegetative	.....
(iii) Flowering	.....
(iv) Fruiting	.....

F PESTICIDE APPLICATION.

52. Please state the primary or main insecticide type you use if any. (*please provide label or container if available*)

☐ Dursban 4 E
☐ Karate 2.5 EC
☐ Deltaphos
☐ Dipel 2X/Biobit
☐ Sumithion
☐ Dimethoate
☐ Others (please specify)

.....
.....

53. Why do you use this insecticide product?

☐ It is always available
☐ It gets rid of insects pest
☐ It is cheap
☐ It is environmentally safe
☐ Others (please specify)

.....
.....
.....

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54. Who recommended this insecticide to you?

- ☐ Fellow farmer
- ☐ Extension officers
- ☐ Chemical retailer/agent
- ☐ Through adverts
- ☐ Others (please specify)

.....

.....

55. Where do you obtain your insecticide?

- ☐ Private retailers
- ☐ Co-operatives
- ☐ From other farmers
- ☐ Govt. institutions (MOFA)
- ☐ Others (specify).....

.....

56. Do you use more than one type of insecticide during one season

☐ Yes ☐ No

57. If yes, name the various insecticides you use?

.....

.....

.....

.....

58. Give reasons why you use more than one type of insecticides on your crop?

.....

.....

59. How do you use the various insecticides?

- ☐ Alternatively
- ☐ As mixtures

60. Give reasons for each applicable situation.

.....

.....

.....

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68. State the precise quantity of insecticide products you mix with water for spraying.

TYPE	Qty of Chemical/ in liters of H_2O
(i)	
(ii)	
(iii)	
(iv)	

(Please mention name of insecticide and quantity used in litres of water)

69. What is the rate per hectare you apply of the insecticide product(s)

Name of product	Rate per hectare
(i)	
(ii)	
(iii)	

(Please mention name of insecticide and rate per hectare)

70. What type of insecticide formulation(s) do you apply?

- ☐ Emulsifiable Concentrate (EC)
- ☐ Dust
- ☐ ULV
- ☐ EC/ULV
- ☐ Others (specify).....

71. Do you use other chemical products for spraying?

☐ Yes ☐ No

72. If yes, list all the chemical products you apply on tomato crop.

(i).....
(ii).....
(iii).....
(iv).....
(v) Others (specify).....
.....

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61. How many times do you spray your tomato crop before harvest?

- ☐ Once
- ☐ Two times
- ☐ Three times
- ☐ Four times
- ☐ Five times
- ☐ Six times
- ☐ Seven times
- ☐ Eight times
- ☐ Nine times
- ☐ Ten times
- ☐ Eleven times
- ☐ Twelve times

62. At what intervals do you spray your tomato crop?

- ☐ 3 days interval
- ☐ 4 days interval
- ☐ 5 days interval
- ☐ 7 days interval
- ☐ 14 days interval
- ☐ 21 days interval
- ☐ Others (specify).....

.....

63. Why do you spray at the intervals that you indicated?

.....

.....

64. After spraying how long do you wait before harvesting?

.....

65. Do you use recommended concentration of insecticide products?

☐ Yes ☐ No

66. Do you adhere to instructions on labels for use

☐ Yes ☐ No

67. If no, why?

- ☐ Usually not available
- ☐ Self (illiteracy)
- ☐ Relies on advice by extension agents
- ☐ Others (specify).....

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73. How do you apply these chemical products?

- ☐ Single
- ☐ Mixture
- ☐ Others (specify).....

.....

.....

74. What application equipment do you use?

- ☐ Hand operated knapsack
- ☐ Mistblower
- ☐ Utra low volume applicator
- ☐ By hand
- ☐ Others (specify).....

.....

75. What are your reasons for your choice of equipment?

.....

.....

76. Do you calibrate your equipment for pesticide application?

☐ Yes ☐ No

77. If no, explain why?

.....

.....

78. Where do you obtain information on instructions for use pesticide products?

- ☐ Own experience
- ☐ Label on containers
- ☐ Friends/other farmers
- ☐ Chemical shops
- ☐ Extension agents
- ☐ Chemical companies
- ☐ Others (specify).....

.....

(More than one answer is possible)

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79. How often do you receive technical advice by an expert?

- ☐ Whenever it is necessary
- ☐ Once per season
- ☐ Once per month
- ☐ Never
- ☐ Others (specify).....

80. Do you use any protective clothing when handling/spraying pesticide?

☐ Yes ☐ No

81. If yes, indicate type of protective clothing you use.

- ☐ Overcoat/Overall
- ☐ Wellington Boots
- ☐ Goggles
- ☐ Respirators
- ☐ Hand Gloves
- ☐ Hat
- ☐ Long sleeve trousers
- ☐ Long sleeve shirt

(*More than one answer is possible*)

82. If no, give reasons why you do not use protective clothing.

- ☐ Can't afford
- ☐ Feel it is not necessary
- ☐ Not available on market
- ☐ Others (specify).....

.....

83. Do you observe any problems with pesticide use?

(*More than one answer is possible*)

- ☐ Phytotoxity (burning of plant)
- ☐ Feeling sick
- ☐ Poisoning by yourself or in the village
- ☐ Others (specify).....

.....

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84. Indicate the main health problems you experience.

- ☐ Dizziness
- ☐ Drowsiness
- ☐ Headaches
- ☐ Stomach problems
- ☐ Eye problems
- ☐ Skin rashes

85. Do you seek medical advice?

☐ Yes ☐ No

86. Where do you store purchased pesticides?

- ☐ Sitting room
- ☐ Bedroom
- ☐ Store room
- ☐ Kitchen
- ☐ Barn on the farm
- ☐ Under a tree on the farm

87. Have you been storing pesticides with other products?

☐ Yes ☐ No

88. If yes, what are the products?

- ☐ Edible parts of plants
- ☐ Spraying machines
- ☐ Water containers
- ☐ Others (specify).....

.....

89. Do you look for expiry dates when buying pesticides?

☐ Yes ☐ No

90. How do you dispose of expired/ unused pesticide?

- ☐ Re-use
- ☐ Bury them
- ☐ Throw away
- ☐ Others (specify).....

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91. How do you use the empty pesticide containers?

- ☐ Use for pesticide again
- ☐ As drinking cups
- ☐ Storing liquid fuel
- ☐ As containers for edible products
- ☐ Throw them away
- ☐ Use for other purposes

92. Do you perceive pesticides as dangerous tools? ☐ Yes ☐ No

93. If yes, give reasons .....

.....

.....

94. Do you think pesticide use is important? ☐ Yes ☐ No

.....

.....

95. If yes, please elaborate .....

.....

96. What can you say about efficiency of pesticides?

Present.....

Past .....

97. Do you have any knowledge on the problems associated with pesticide mis-use? ☐ Yes ☐ No

98 If yes, what are some of the problems you know?

- ☐ Killing of beneficiary insects
- ☐ Food contamination
- ☐ Resistance development
- ☐ Environment contaminations
- ☐ Poisoning during application
- ☐ Others (specify).....

.....

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G SOCIO ECONOMICS.

99. How do you use your tomato?

- ☐ For home consumption
- ☐ For local consumption
- ☐ For export
- ☐ others (specify).....

100. How do you market your tomato crop? *(please elaborate if applicable)*

.....

.....

.....

101. What is the average yield of your tomato crop per acre? (*in crates*)

.....

102. What is the average price per crate in the season?

.....

103. Did you try to count your field expenditure and income from sale?

☐ Yes ☐ No

104 On the average, what is the net returns per acre on your investment

.....

.....

Thank You

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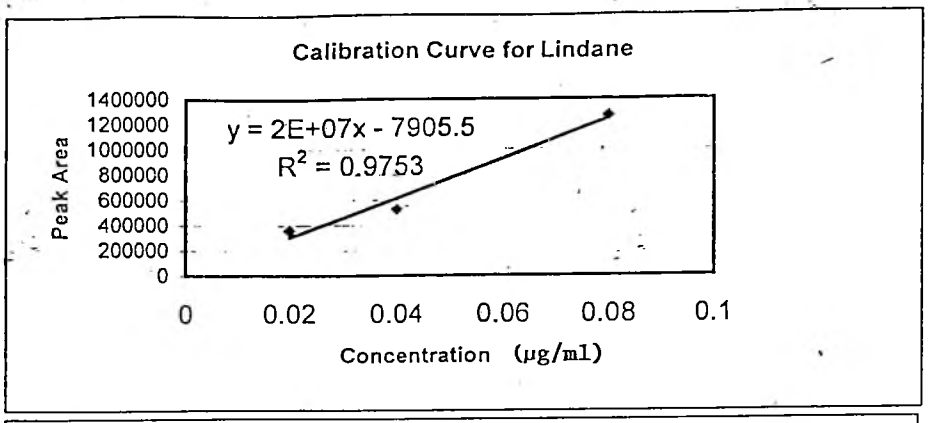

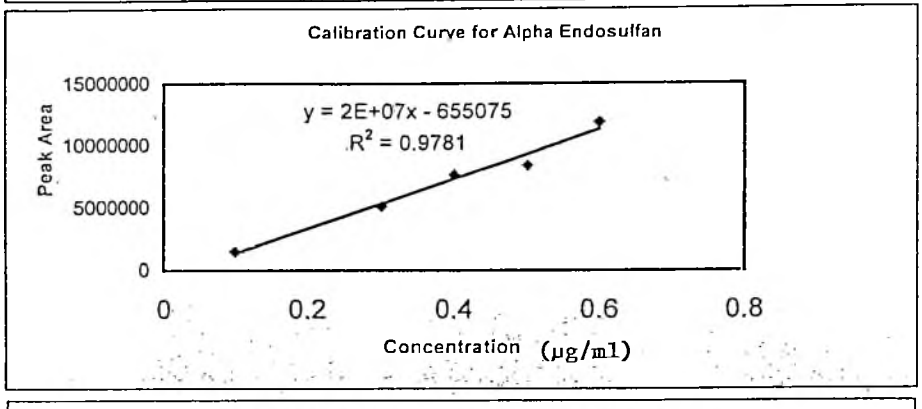

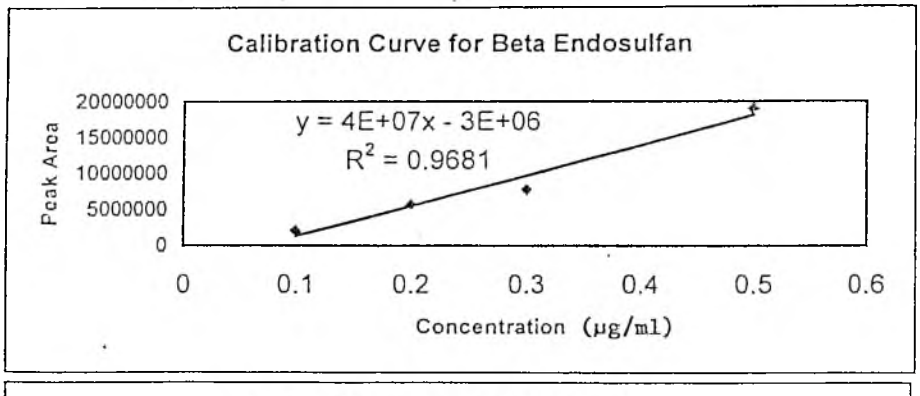

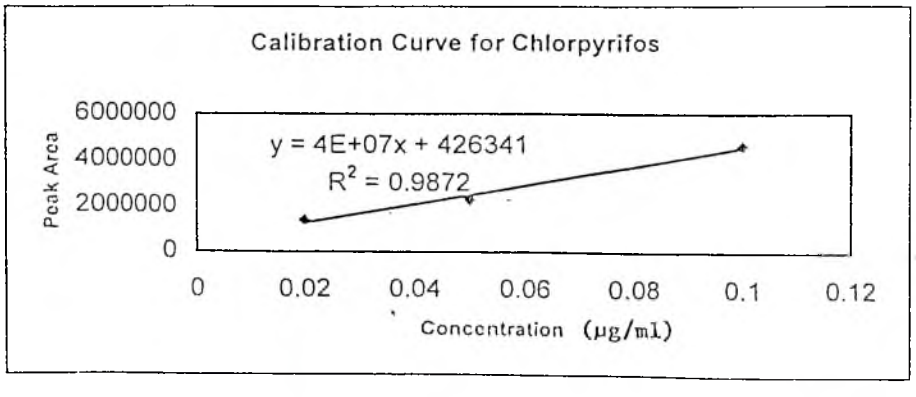

Calibration curves for insecticide standards: (C) Lindane, (D) Alpha Endosulfan, (E) Beta Endosulfan, (F) Chlorpyrifos