# A SURVEY OF PESTICIDE USE IN GREENS AND SPINACH PRODUCTION IN NORTHEASTERN OKLAHOMA

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# CHAPTER I

# INTRODUCTION

The introduction of synthetic organic chemicals after World War II opened a new era in agriculture. Antle and Capalbo (1986) argued that though pesticides are believed to have brought a major source of growth in the productivity of U.S. agriculture, this growth came at some cost. Lichtenberg and Zilberman (1986) contended that use of pesticides in farming indicated a promise for effective management of insect and other animal pests, diseases and weeds. Matthews (1979) revealed that without chemical control, man's crops would be attacked by insects, weeds and diseases leading to serious decline in food production. He further noted that despite intensive research on alternative control methods, chemical control is still a very powerful and effective method of controlling pests.

Pesticides are used to control, prevent and destroy pests. They continue to be important tools in protecting our food and fiber from insects, diseases, weeds and rodents. They are also important tools in controlling insects that carry human diseases and help maintain our comfort by controlling biting and nuisance pests in our indoor and outdoor living areas. Pesticides generally vary to a great extent in the way they are designed to control pests (Criswell, 1992). Pesticides include: herbicides, fungicides, insecticides, rodenticides, miticides or acaracides, bactericides, nematicides, repellents, avicides, harvest aid and plant growth regulators. Herbicides are chemicals used to kill unwanted plants (weeds) or control their growth. Insecticides are chemicals used to control or kill insects and other related animals. Fungicides are chemicals used to control or kill fungi that cause various plant diseases. Rodenticides are chemicals used to control mice, rats and rodents. Miticides or acaracides are chemicals which control tiny arthropods such as mites and ticks. Bactericides are chemicals used to control or prevent bacteria which cause diseases. Nematicides are chemicals used to control nematodes (Criswell, 1990). Repellents are chemicals used to divert insects from crops, animals or structures. Avicides are chemicals used to control birds. Harvest aids are chemicals used to harvest crops more effectively such as cotton defoliants. Plant growth regulators are used to change normal growth of plants by accelerating or retarding the normal rate of production (Bode, Pearson, Jacobson, Shurtleff, Meglamery, Anderson, Moore, Gentry and Williams, 1981).

Pesticide research and development and the advancement of agriculture have historically gone hand in hand. As populations increased, modern agriculture responded quickly to fulfill their demand for food and fiber. Pesticide improvement and availability contributed to the improvement of agricultural productivity and therefore to the total improvement of U.S. Agriculture.

Agricultural pesticides are one of the integral inputs of modern agriculture (Agriculture Board, 1972). The increased productivity in agriculture under the influence of applied science has been so great that economist Malthus' warning of a limited food supply for the world's population seemed, for a time, unimportant (Green, Hartley and West, 1977).

At present, population is increasing annually at 1 percent in the developed countries and 2.5 percent in the developing nations (Finley and Price, 1994). At this rate the world population was estimated to be 5.722 billion in 1993 (U.N., 1993). The U.S. population was 250.87 million in 1991 (U.S. Dept. of Commerce, 1993). By the year 2000 the U.S. population is estimated to be 273.65 million at a growth rate of 0.9 percent (U.S. Dept. of Commerce, 1993). By the year 2100 the U.S. population is estimated to be 308.7 million (Finley and Price, 1994). To feed this ever increasing population, scientists are constantly working to increase the productivity and efficiency of agriculture. Use of pesticides to protect crops from damage by pests is an outcome of scientific research.

Control Methods for Pests

Pests compete with humans for food at both primary and secondary production levels (Bunting, 1972), during preharvest, postharvest and storage periods. Pests not only consume crops but also destroy harvested produce, weaken livestock, spread disease and create a nuisance (Graham-Bryce, 1987).

The earliest recorded attempts at pest control were mainly concerned with the biology of the pests and their ecology. Through numerous cultural and physical methods people attempted to make the environment less favorable to the growth of pests (Hill, 1987). At present there are many methods of pest control: Legislative, Physical, Cultural, Crop plant, Resistance to pest attack, Biological, Chemical, Integrated Pest Management (IPM) and Eradication (Wilson, 1974; Hill, 1983).

Among all the methods of pest control, chemical control has been most prevalent since World War II (Hartley, 1972). The modern chemical control dates back to World War II (McEwen and Stephenson, 1982). Prior to that, pesticides were mainly sulfur or lead arsenate (inorganic) along with a few naturally occurring materials like pyrethrum and nicotine, which are organic (Green, Hartley and West, 1977).

Use of pesticides to control pests is known as a chemical method of controlling pests. According to Smith and Secoy (1975) chemical poisons were used from the earliest times to control pests. Graham-Bryce (1987) noted that chemical methods of controlling pests provided its users with an apparent means to meet the objectives of controlling pests. The first half of the 20th century witnessed a wide spread and systematic use of different chemical materials, especially inorganic substances. It may be recalled that the discovery of DDT in 1942 opened the prospects and a new era of synthetic organic pesticides (Hassall, 1969; Graham-Bryce, 1987).

Problems with Chemical Control

Available data indicate that the use of chemical pesticides and the various problems associated with their applications are not likely to diminish in the near future (Antle, 1988). The success of pesticides for crop protection also leads to problems (National Academy of Sciences, 1972). There is presently a growing public concern about the impact of toxic chemicals on health, the environment and food safety (Baker and Crosbie, 1994). To reform U.S. pesticide laws, specifically regarding food safety, the Clinton Administration has unveiled proposed legislation (National Environmental Health Association, 1994) which attempts to change the standards for pesticide residues on food and empower the Environmental Protection Agency (EPA) and Food and Drug Administration (FDA) with added measures for providing higher protection to the environment as well as the American people. The most important features of the present legislation are: a) development of new alternatives for pest management materials; b) federal programs for research on those alternatives; and c) rationalization of the registration process. The rationalization process will help farmers have access to new tools that will exhibit lesser risks to the environment and to human health.

Use of Pesticides and the Importance of
Greens and Spinach Production

The foregoing discussion suggests that producers of agricultural crops use pesticides to protect their crops, and that the use of pesticides are not free from human and environmental hazards, which has necessitated the adoption of available alternatives for the use of pesticides.

With this background, it should be emphasized that as with most agricultural products, the use of pesticides in the production of greens (collards, kale, mustard, spinach and turnip greens) in Northeastern Oklahoma is of vital importance. A study by Correll, Morelock, Black, Koike, Brandeberger and Dainello (1994) indicated that Oklahoma was one of the major spinach production states. Other spinach producing states are: Texas, Arkansas, Maryland, Virginia, New Jersey and Colorado (Ryder, 1976).

Spinach and other greens are leafy vegetables of economical importance. They are used in salads and processed. Many studies have been conducted in recent years addressing various aspects of the use of the pesticides on vegetable crops (Johnston, 1991). It has been demonstrated that many pesticides are biodegraded in the subsurface under a multiplicity of conditions. According to Sabatini and Austin (1990), the phenomenon of sorption and desorption are main issues for the movement of pesticides in ground water.

It is an established fact that pesticides help increase crop yield and also cause hazards to human beings and the environment. But many questions remain, especially at the grass-roots level regarding use of pesticides on particular crops, thereby affecting various environmental factors like patterns of present usage and alternative controls. The question to be addressed is whether growers or food processors who are involved in the production and processing of greens and spinach are willing to adopt alternative control methods and what their perceptions are about such methods.

A plethora of literature has documented that U.S. farmers, as well as the public, had to face some problems in their agricultural practices, especially with the use of chemicals which came into direct conflict with environmental objectives. The U.S. people in particular and people of other parts of the world in general are by now familiar with issues such as environmental safety, ground water contamination, food safety, farm workers' and public health safety, farm land covservation and preservation, farm profitability, economic benefits costs and social issues associated with pesticides.

As demonstrated in the literature review, use of pesticides presented a dilemma for the producers of agricultural goods as well as for society. The present dilemma owes its origin to two conflicting issues: benefits of pesticides, and the cost to society. The abundance of literature showed that pesticides had beneficial effects on higher quality and increased quantity (yield) of agricultural production (Wilcott, Johnson, and Long, 1991). Similarly, society had to pay the costs for such benefits in terms of their health and environmental damage. The issue of pesticide usage, no doubt, is of greater importance and interest to a larger portion of society, viewed from various perspectives, such as benefits-costs and also how to make the world a safer place to live. In this context, alternative agriculture has a renewed role to play to meet the changing demand of the society. As Young (1991) stated:

> Growing awareness and concern about the linkages between agricultural policies and specific environmental problems, some of them with serious long term implications, have focused increasing attention on the interface between agriculture and environment. This has led to a recognition of the need to better integrate agricultural policies with policies which seek to protect, preserve, and enhance the environment. It is believed that by pursuing integrated policies more sustainable agricultural production systems will emerge (p. 1).

In alternative agriculture, a systems approach is necessary. The area of alternative agriculture or alternative control methods in agriculture is aimed at giving present and future agriculturists the benefit of meeting the growing demand of environmentally safe and pesticide-free food. Alternative agriculture is not anti-technology. On the contrary, it attempts to make technology compatible with environmental protection (The League of Women Voters Education Fund, 1989). But the practice of alternative control methods and use of pesticides by the food processors processing greens and spinach in Northeastern Oklahoma were not known. For this specific cause it was deemed to be important to assess the present use of pesticides and determine the alternative agricultural control methods practiced by these food processors.

## Problem Statement

The value of pesticides for increased crop production and higher yields is accepted by most farmers and most business persons. But there are also concerns about pesticide use. Efforts are needed to minimize pesticide use while maximizing production levels. After World War II chemical pesticide and fertilizer use increased at a steady rate (Duffy, 1991). However, in the case of Northeastern Oklahoma, the proportion of acreage for greens and spinach treated with pesticides, alternative control methods used and perceptions of the growers and/or food processors regarding alternative control measures were not known. It was important to know the types and quantity of pesticides used and pests treated. An assessment of the extent to which these practices were followed was needed to determine the future use of pesticides.

## Purpose of the Study

The main purpose of the study was to determine the usage of pesticides, cultural practices and alternative controls in the production of greens contracted by the food processors in Northeastern Oklahoma. An auxiliary purpose of this study was to document the availability of alternative control methods to replace pesticides. The rationale behind this was that unless the views of the field level personnel involved in the production process were known, no recommendations or regulation in any area about the use of pesticides or its alternatives would be effective. This study, therefore, attempted to search those viewpoints vis-a-vis the current usage of pesticides in Northeastern Oklahoma.

## Objectives

The specific objectives of this research were to:

1. Determine number of acres and varieties of greens and spinach planted, harvested and average yield obtained per acre;

2. Determine acres treated with pesticides and types of pesticides used (insecticides, herbicides and fungicides);

3. Determine methods of application of pesticides;

4. Identify pests which caused the greatest financial loss;

5. Determine the trends of pesticide usage during 1990-1994;

6. Determine alternative control methods used (including cultural practices to control pests (insects, diseases and weeds);

7. Determine methods of monitoring fields against pests (scouting);

8. Determine food processors' views on Integrated Pest Management (IPM); and

9. Determine what assistance the food processors would like from the Oklahoma Agricultural Cooperative Extension Services (County Extension Agents) and IPM area specialists to accomplish improvements in their business.

## Scope of the Study

The scope of this study included all four food processing industries currently processing greens in Northeastern Oklahoma with producers in Adair, Cherokee, Wagoner LeFlore, Muskogee, Haskell, Sequoyah, and Tulsa counties in Northeastern Oklahoma and Caddo county in Southwestern Oklahoma.

## Assumptions

This study was based on the following assumptions.

1. The food processors surveyed were experienced and knowledgeable about the use of pesticides.

2. The food processors surveyed answered the questionnaires diligently and honestly.

3. The food processors' opinions, perceptions, comments and recommendations and opinions were not biased.

## Limitations of the Study

The results of the pesticide use survey are limited to the answers/opinions provided by the food processors. As some answers concerning some crops were not as complete as desired and the population was small, empirical pesticide use and pest control data should be interpreted with caution.

# CHAPTER II

## REVIEW OF LITERATURE

The purpose of this chapter was to lay a foundation of the theoretical background of the use of pesticides, and subsequently to emphasize a need for alternative agricultural production methods. This review focused on both the past and present trends of the two conflicting, but still co-existing issues of today's agricultural industry which are: use of pesticides and alternative practices, including Integrated Pest Management (IPM). This literature review was developed by emphasizing the following categories such as importance and development of pesticides, views on pesticide usage, and alternative practices in crop production. The author felt that such classification would result in a systematic and more clear review.

Based on the categories mentioned above, literature review on both pesticides and alternative practices is presented in the following order.

1. Introduction
2. Historical Trends
3. Environmental issues
4. Definitions and Classifications of Pesticides/Chemicals; Alternative Agriculture; Cultural Practices; Integrated Pest Management (IPM)
5. Economic Importance of Alternative Agriculture
6. Place of Agriculture and Need of Further Knowledge, Education, and Extension.

7. Importance of Greens (collards, kale, mustard, turnip greens) and spinach and their methods of cultivation

8. Common insects, diseases and weeds which attack these crops, and control measures for these pests.

9. Utility concept, benefit--cost and decision criteria.

## Introduction

> It is common place that the outside of things are different from the inside, as we prove when we cut off the cheese rind or peel an orange before eating them. Chemists have long known certain molecules behave differently at the surface of a solution from those in the bulk. Biologists, on the other hand, have always understood that the surface of an organism is its first line of protection against external forces and alien bodies. The unusual properties of surfaces provide living organisms with a protective layer which modified the exchange of chemicals including pesticides.
>
> The applied science of crop protection, which is barely half a century old, studies among other problems those arising from the application of biologically active chemicals on the surfaces of plants, with the objective of removing unwanted species or of controlling insect and fungal attack. This has created interesting interfaces between a number of quite different scientific disciplines (Cottrell, 1987, p. VII).

Over the past few decades public concern, awareness and recognition regarding the issues concerning the environment and use of pesticides have been increasing. As a result there exists a substantial legislation and regulatory process for regulating the usage of pesticides (Sheets and Pimentel, 1979).

In maintaining the momentum of improved agriculture there are both risks and benefits from pesticide use. General risks include potential health problems for humans and other species in this world. But the percentage of environmental hazards that are caused solely by the use of pesticides is difficult to assess. The National Academy of Sciences (1975) examined two caveats of the problem of human health hazard detection such as epidemiological data and studies on laboratory animals. The Academy indicated that they could not associate the nationwide mortality data with the period of "onset of major use of modern pesticides" (p. 4). However, they examined problems associated with pesticides on health hazards using data from epidemiological and laboratory animals studies. Detection of carcinogenic hazards which created the greatest concern with pesticide use was an issue of major importance of this study. It was recommended by the Consultative Panel on health hazards of chemical pesticides:

> That the carcinogenic risks, and other health hazards of pesticides require continuing evaluations by testing with laboratory mammals; and that despite the problems involved in translating the results from such experiments to human risk, the present techniques are sufficiently reliable to justify registration actions based upon such data alone, on an interim basis, until evidence convincingly demonstrates that there is no human risk (National Academy of Science, 1975, p. 5).

The National Research Council (1989) noted that some production practices such as extensive and excessive use of pesticides were contributing problems to environmental, occupational, and public health. In addition, improper use of pesticides, such as incorrect application dosage or poor application techniques result in extensive losses of crops (Pimentel, Andow, Gallahan, Schriner, Thompson, Hudson, Jacobson, Irish, Kroop, Moss, Shepard and Vinzant, 1980). Pimentel et al. (1980) further noted that about 65 percent of all agricultural pesticides were applied by air. Moreover, as indicated by the National Academy of Sciences (1975) 17 million pounds of herbicides were used annually to clear rights of ways and highways. Not only that, but drift injury to crops due to application of herbicides were enormous. As cited by Pimentel et al. (1980):

> Drift injury has been reported in Oregon on sugar beets, potatoes, fruit crops, and almonds (Brown, 1978), in Indiana on tomatoes and soybeans (Bauman, 1978), in Mississippi on cotton (Hurst, 1978), in California on spinach, lettuce and pears (Elmora,1977), in Alabama on forages (Walker, 1977), in South Dakota on soybeans (Auch and Arnold, 1978), and in North and South Dakota on sunflowers (Arnold, 1979, p. 26.)

It is interesting to note that the cost of applying pesticides was $2.2 billion annually for treating 20 percent of the crop lands. This cost did not include indirect costs (Pimentel, et al.

1980). Indirect costs comprise social costs, environmental costs and costs incurred due to government regulations to control possible adverse effects on pesticides. Pimentel et al. (1980) estimated that the investment of $2.2 billion prevented a crop damage of $8.7 billion which was 9 percent of current crop production. They also estimated the indirect cost of use of pesticides (only for which quantitative data was available) stood at $840 million. These indirect costs include insurance costs, natural enemy losses and pest resistance to crops. Certainly this could not take into account unquantifiable damage to the environment caused by pesticides. Many will argue that the estimate was subjective (Newsom, 1979). Moreover, how can you put a value on the loss of human life? Of course those are the questions to be answered by the society when agreeing or disagreeing on the use of pesticides. In general it is agreed that use of pesticides reduced crop losses to a great extent. Pimentel (1979) argued that crop losses due to insect pests increased nearly two fold from the 1940s to the present (from 7% loss to 13% loss) although there was a 10 fold increase in insecticide usage. He estimated that the loss of all crops due to pests to be 33 percent (Insects 13%, diseases 12% and weeds 8%). Lichtenberg and Zilberman (1986) indicated that some authors have argued that crop losses would average 50 percent and more without pesticides. McEwen's (1978) estimate on loss of crops without pesticides was lower. However, Lichtenberg and Zilberman(1986) revealed that a return of $3.00 to $5.00 for every $1.00 spent on pesticides was a widely used range of calculation by many authors. Though there exists variation in estimates in the return of money invested on pesticides, the apparent benefit cost ratio at 4:1 found by Pimentel et al. (1980) naturally justifies attempting to find out some way to tax those people who are getting advantages from the use of pesticides and enjoying the benefits at the expense of others.

## Historical Trends

If demand for pesticide regulation is large, one might expect more stringent pesticide regulations in the future from state or federal government (Horowitz, 1994, p. 396).

Pests inhabited this world long before man came (Pfadt, 1972). The prevalence of using toxic chemicals to control pests existed from time immemorial (Hassall, 1969). In Homeric poems written about the 8th century describing the social customs and legends many centuries old, the use of sulfur as a cleaning (purifying) agent was indicated (McCallan, 1967; Hassall, 1969). During the sixteenth century, the Chinese employed moderate quantities of arsenical compounds as insecticides. Pyrethrum, a plant, was used as a natural insecticide by 1828 and soap appeared as insecticide by the middle of the nineteenth century (Hassall, 1969). By the nineteenth century both soap and pyrethrum were used to control insects. A mixed wash of sulfur, tobacco, and lime was used to control fungi and insects. Cremlyn (1978) pointed out that soap and sulfur were used to kill aphids and served as fungicides on peach trees. In 1761, Schulthess used copper sulfate to treat bunt and also used it as a fungicide (Torgeson, 1967).

McCallan (1967) citing Lodeman noted that in the U.S. Kenerick possibly prepared the first self-boiled lime sulfur in 1833. According to Cremlyn (1978), Forsyth described a mixed wash with tobacco, unslaked lime and sulfur to control fungi and insects. In 1850 Duchatel applied sulfur dust to grape leaves. This led to the discovery of fungicide application by dusting (Large, 1940). In 1867, Paris green, an impure copper arsenate, was introduced as a result of experiments with new arsenical compounds (Hassall, 1969; Cremlyn, 1978). Hassall (1969) referring to De Ong (1956) mentioned that the Paris green was so widely used to combat colorado beetle and codlin moth that its widespread use led to the first state legislation controlling the use of insecticides in the U.S.

Boullie Bordelise or Bordeaux mixture was introduced in 1886, and was invented by Gayen and Millardet in France with mixtures of copper sulfate, water and lime to treat downy mildew (McCallan, 1967). This was a valuable chemical treatment to combat pathogenic fungi such as vine mildew and potato blight.

A tremendous attempt to further improve the Bordeaux mixture formulation took place from the period of Millardet to 1959. A French farmer, while applying Bordeaux mixture in his grape fields, noticed that the leaves of yellow char lock which grew nearby turned black (Hassall, 1969; Martin 1973). This very chance observation facilitated the ideas of herbicidal control methods. Afterwards, it was noticed that iron sulfate, if sprayed on to a mixture of cereal weeds killed the weeds without damaging the crops. Later on, other inorganic substances such as sodium nitrate and ammonium sulfate acid were found to have selective properties if applied at a suitable concentration level.

From the above it may be said that the efficiency of Bordeaux was discovered accidentally in 1882 (Tschirley, 1979). Since that discovery copper sulfate and Bordeaux were being used to control diseases. Use of arsenicals, however, date back to 1681. Oil sprays were introduced in 1877. As noted above, it appeared that lime-sulfur, arsenicals, nicotine and petroleum oils were the principal insecticides prior to World War I. Compounds like pyrethrum, rotenone, florin compounds, dinitro compounds and thiocyanates appeared in the market during World Wars I and II (Tschirley, 1979; Hassall, 1969).

The development of chemical weed control started in 1908 when Bolley experimented with weed control techniques in wheat production using copper sulfate, sodium arsenite, iron sulfate and salt. Mass use of selective organic herbicides like hydrocarbon oils and dinitro-orthocresol was witnessed just before World War I (Hassall, 1969).

In 1940 chloranil came on the market as a seed dressing. That stimulated the development of new fungicides such as glyoxalidine, guanidine, nitrobenzene and others (Hassall, 1969). However, during the second World War discovery of DDT in Switzerland and insecticidal organophosphorus compounds in Germany made a turning point in the use of pesticides (Hassall, 1969; Cremlyn; 1978 and World Health Organization, 1990).

In brief, the 1940's and 1950's featured significant discoveries in the use of chemicals. This helped the development of a successful agricultural system which accentuated the economic muscle of the U.S. and also secured the health of the public from vector transmitted diseases (Young, 1987).

During 1950 to 1955 urea derivatives were developed as herbicides in the U.S., and fungicides--captan, glyodin and malathion, were introduced on the market (World Health Organization, 1990). During the period 1955 to 1960, other herbicides -- triazines and quaternary ammonium, were added to the market (World Health Organization, 1990). Bromoxynil, dichlobenil, and trifluralin were discovered during 1960 to 1965. Benomyl, a systematic fungicide appeared on the market in 1968. Shortly after this, glyphosate, the leaf acting herbicide, came on the market.

Many pesticides based on biochemical/biological mechanisms (e.g. herbicidal, sulfonylureas, fungicides (systemic), metalaxyl, and triadimefon) were introduced during the 1970's and 1980's (World Health Organization , 1990). The new insecticides comprising synthetic light-stable pyrethroids were laboratory developed to mimic the naturally occurring pyrenthrins. However, chemical control was neither popular nor very successful until the late 19th and the early 20th centuries (Antle, 1988).

It is interesting to note that during the 1950's and the 1960's it was conceived that wide scale use of chemical pesticides could solve pest problems bearing a low cost to the society (Antle, 1988). These ideas gained such a broad acceptance in the agricultural sector that there were more than 32,000 pesticide products containing nearly 1000 chemicals registered for use in the U.S. in 1970 (Tschirley, 1979; Hynes, 1989). According to a 1963 estimate, about 90,000 tons of herbicides were applied annually on ninety million acres in the U.S. at the rate of 2.2 LB herbicide per acre under cultivation (Shaw, 1963).

Historically, in 1962 a very significant event happened with the publication of the book "Silent Spring" by Rachel Carson (Tschirley, 1979). Tschirley (1979) noted Carson's book carried a clear message that society should be concerned about the potential adverse effects of the higher amounts of pesticide exposure into the environment. Sheail (1985), a British historical geographer, noted that Carson's publication made a blistering attack on the indiscriminate use of pesticides to subdue insects, diseases and weeds in crops. McCallan, (1967) while writing a history of fungicides noted that:

> The publication of the controversial best seller 'Silent Spring' by Rachel Carson (1962) focused popular attention on the residue problem with a vengeance. While residues are of paramount importance with insecticides, they cannot be ignored with fungicides (p. 28).

However, in spite of some errors and misinterpretations contained in 'Silent Spring' total pesticide production in the U.S. more than doubled in the last 15 years following the publication of this book (Tschirley, 1979). Although DDT was the dominant pesticide used in the U.S. from the late 1940's to early 1960's, it was canceled in the U.S. in 1972 (Eisenreich, Baker, Franz, Swanson, Rapport, and Hites, 1992). In this context, Willas (1993, p. 166) noted:

> Why is there DDT in the bodies of every American - in fact, in animals from Antarctica to the North Pole? Why do farmers have worse weed problems now than their grandfathers had? Are toxic chemicals really necessary to control weeds and pests?

However, whatever may be the question raised by Willas, the production of pesticides did not decrease. According to National Research Council, "the total pounds of pesticides active ingredients applied on farms increased 170 percent from 1964 and 1982, while total acres under cultivation remained relatively constant" (p. 44). This was partly because chemical technologies permitted more intense use of land and farmers availed the profligate use of such chemical technologies. (Farrell, 1986, p ix). The total pesticide use in the U.S. on major crops is shown in Table 1.

TABLE I

TOTAL PESTICIDE USED BY U.S. FARMERS ON CROPS

| Year | Herbicides (Million Kilograms) | Insecticides (Million Kilograms) |
|---|---|---|
| 1964 | 34.5 | 64.9 |
| 1966 | 50.8 | 62.6 |
| 1971 | 101.6 | 71.7 |
| 1976 | 178.7 | 73.5 |
| 1982 | 196.4 | 26.8 |

Source: Council on Environmental Quality, Adapted from Young (1987, p. 3)

Matsumura (1972) reviewing the current use of pesticides situation in the U.S. outlined that in 1969, production and sales of synthetic organic pesticides declined for the first time since 1957. Use of DDT continued its decline and comprised 62% of the peak use of 1959. But it needs to be mentioned that the U.S. is the World's largest market (as consumer) of pesticides which represents 34 percent of the total consumption (Young, 1987).

Society is now becoming very concerned with agricultural use of pesticides. Due to various adverse effects of pesticides, their indiscriminate use has been questioned. For example, Mellor and Adams (1984) in a study on pesticide use concluded that pesticides could have a detrimental impact on the environment. As an example they cited the use of fungicide benomyl. This fungicide they pointed out might unleash damaging outbreaks of foliage-feeding caterpillars.

The foregoing discussions described how pesticides were developed and used for agricultural development. These discussions were heavily drawn from McCallan (1967); Hassall (1969); Tschirley (1979); World Health Organization (1990) and Sheail (1985).

## Environmental Issues

> No longer is it enough to protect man from natural hazards; the environment must also be protected from the more hazardous activities of man (Sheail, 1985, p. 234).

Although pesticides were being used for many years, people's concern for its environmental effects is of recent origin (McEwen and Stephenson, 1982). The environmental problems facing U.S. agriculture are diverse. A World Health Publication (1990) noted that with pesticides that have a high active toxicity but are readily metabolized and/or eliminated, the main hazard is in connection with acute short term exposures. With other pesticides which have a lower acute toxicity but show a strong tendency to accumulate in the body, the main hazard is in connection with long term exposure, even to comparatively small doses. Other pesticides that are rapidly eliminated but induce persistent biological effects, also present a hazard in connection with long term, low-dose exposures. Adverse effects may be caused not only by the active ingredients and the associated impurities, but also by solvents, carriers, emulsifiers and other constituents of the formulated product.

Matsumura (1972) noted that among environmental contaminants pesticides enjoyed a unique place, though pesticides were present in a small quantity in the environment compared to other contaminants such as fertilizers and industrial wastes. The principal factor which accounted for public and scientific concern was their biological activity.

While emphasizing environmental issues, Moore (1970) observed that we were living in a unique and critical time. Some of these problems were so new that history could not provide any workable guidance to resolve them. Earlier, problems affecting the environment due to pesticides were local events. But now the effects are felt on a broader scale such as regional, national, and international. Therefore, Sheail (1985) who documented the impacts of pesticides on wildlife observed that it was no longer enough to safeguard man from natural hazards. The environment must be saved from increased hazardous activities of man.

However, the huge and varied productivity of the chemical industry and large scale use of chemicals (pesticides) in the agricultural sector indicated that human beings would continue to experience long term exposure to chemicals (EPA, 1979). The other major issue on environmental damage due to pesticides is ground water contamination. It may be mentioned that in the U.S. over 97 percent of all rural domestic water, 40 percent of all irrigation water, and 55 percent of livestock water comes from underground sources (Solley, Chase, and Mann, 1983).

According to Nelson and Lee (1987) there are documented and suspected risks to human beings from exposure to contaminated ground water. The relative share of agriculture contributing to ground water contamination was significant (National Research Council, 1989). Ground water contamination through agricultural chemical application is a non-point source (diffuse). The use of inorganic nitrogen fertilizer was a source of ground water contamination. Other potential contaminants were wastes generated from concentrations of livestock, poultry and dairy operations, increased conservation tillage practices, disposal of industrial wastes and coverage of more irrigated lands. It was however, alarming to note that more than 19 million people obtained their drinking water from private wells in 1437 potentially contaminated counties. According to a 1987 estimate by Nelson and Lee more than 65 percent of these people lived only in potentially contaminated pesticide areas and a little less than 10 percent lived in potentially contaminated nitrate areas. The rest of the population lived in areas potentially contaminated with nitrate as well as pesticides. Moreover, about one third of the people estimated to depend on ground water as their source of drinking water used private wells. Users of private wells had more chances of drinking contaminated water.

The other important issues affecting the environment is the prevalence and distribution of pesticide residues upon various plants, crops and food. In this respect Ambrus (1979) emphasized that three factors such as (1) Application (2) Crop and Environment and (3) Disappearance influenced the distribution of pesticide residues on a treated field. He made this observation while studying the residues of zineb and mancozeb on tomato and phosphamidon on apples. In studies conducted by Hafner (1976) and Van Middelem (1956) on lettuce, radish, cress and on cabbage and celery respectively, indicated that different plant habits and growth could result in different residues from one plant individual to another on the same field. Moreover, similar surface deposits gave different levels of residues which depended on the surface/volume ratio or size of the individual crop.

Ripley and Edgington (1983) reviewed the factors that affected dissipation of a pesticide after application to explain the decrease in surface residues due to hydrolysis on photo decomposition, or to physical properties like vapor pressure, water solubility or partition coefficient or volatilization. They found that disappearance curves for most foliage-applied herbicides exhibited an exponential decline. They further noted that formulation could also be an important spray deposition. Kirkwood (1987), however, in his study on herbicides indicated that factors like volatility or runoff, or long run persistence of low concentrations in the plant which might cause losses in the initial period after deposition should be accounted for. He argued that it might be possible to get good correlations for weather or time variables alone. However, it may not be possible to determine the relative importance or contribution of a particular variable.

However, effects of pesticides for environmental poisoning of all forms of wildlife, which play some role in the ecosystem, are important health issues. Stability of the environment is also a matter of serious concern. The Council of Environmental Quality (1971) stated:

> From the available evidence, it would appear that populations of many - but by no means all - species of nongame wildlife are declining to some degree. The species high on the food chains particularly the large predatory mammals and birds, appear to be deeply affected. Animal control activities, especially, those using poisons, combined with pesticides and other toxic substances in the environment also contribute to the decline. Pesticide residues and other toxic substances are concentrated as they pass up through the food chain. This means top predators receive particularly high dosages. Either this is lethal in itself or it may affect reproduction by causing a thinning in egg shells of birds. Research in 1970 showed thinning of egg shells in 21 bird species, most of which are fish eaters. Declining populations have been related to this thinning in six or seven species. The nearly total reproductive failure of the Brown Pelican off California and the current decline among Eastern Brown Pelicans has been traced to shell thinning and pesticide residue content. A 1970 survey by Cade and Fyfe (published in the Canadian Field Naturalist) of Peregrine Falcons in North America concluded that the falcon population was continuing a marked decline because of exposure to chlorinated hydrocarbons, and that 'at the current rate of decline, the peregrine may become extinct in North America in this decade'
> (p. 233).

Similarly pesticides in fish are also a cause of great concern. Giesy et al. (1994) conducted research on contaminants in fishes which contain synthetic hologenated carbons and mental' (p. 202). They found fishes of the Great Lakes became contaminated with concentrations of hazardous chemicals such as 2, 3, 7, 8 - tetrachlorodibenzo-p-dioxin equivalents (TCDD-EQ), total DDT complex, aldrin, dieldrin, endrin, heptachlor, heptachlor epoxide, mercury (Hg), and total polychlorinated biphenyls (PCBs), etc. Their findings revealed that fish could move from the lakes into the Great Lakes tributaries of Michigan. While moving from one place to another, fish transported concentrations of contaminants which carried a risk to wildlife. Gisey et al. found that mean concentrations of DDT and most other pesticides were higher in composite samples of six species of fishes from below than above the dams on the Muskegon, Manistee and Au Sable rivers. Previous research studies of Gilman et al. (1977); Weseloh et al. (1979, 1989), Bowerman et al.

(1990), Allan et al. (1991) and Gilbertson et al. (1991) also confirmed that fish of the Great Lakes became contaminated with inorganic and organic chemicals. Moreover, these chemicals biomagnified and bioaccumulated into the tissues of fish eating predators populations.

However, along with environmental and ecological damages caused by pesticides and other chemicals, they are also considered to be associated with cancer. Moreover, some studies in both humans and laboratory animals found association with chronic diseases and environmental chemicals (EPA, 1979); and cancer was a major illness that was strongly correlated with environmental factors (National Academy of Science, 1975).

Chemical factors such as natural, fungal or plant toxins in crops, synthetic pesticides (fertilizer, fuel additives, household and industrial chemicals), and organic and inorganic mixtures (Epstein, 1974), biological factors such as microbes and parasites (Gross, 1978; Heath et al. 1975), and physical factors such as exposures to ultraviolet light and ionizing radiation (Jablon, 1975; Upton, 1975) substantially contributed to cancer incidence to human society.

Boyland (1969) found that ninety percent of human cancers were caused by chemical agents. Not only that, one of the most sensational news items according to Cancer Facts and Figures (1978) was that eventually one out of four U.S. inhabitants would develop cancer.

The foregoing discussion evidenced how pesticides caused immense damage to the human society and the environment. This evidence suggest that scientists should endeavor to find some workable alternatives to the mass use of pesticides. These attempts would possibly help safeguard present and future populations of the U.S. and the world.

It may be mentioned here that the pesticides which crop producers use do not perish in the soil. Parkins and Shelton (1994) conducted a study on modeling environmental effects on enhanced carbofuran degradation. They noted that microbial degradation was an important system controlling the remains of pesticides in the soil. Parkins and Shelton's (1994) study showed that pesticide-degrading micro-organisms, pesticide and population densities, soil parameters like pH, soil water content and temperature and pesticides bioavailability were a function of rates of pesticide degradation. They indicated that moisture and temperature were two environmental parameters which controlled microbial degradation of pesticides in the soil. Their study quantified the impact of soil water content and temperature on microbial degradation rates of the insecticide carbofuran. They determined carbofuran degradation by monitoring the carbon dioxide production from soils amended with carbofuran. Their techniques may be used to develop models for predicting enhanced rates of biodegradation in the field.

To sum up, the state of the global ecosystem is central to maintaining production systems. People use natural resources and pesticides and consume agricultural products. Changes in the chemistry of the atmosphere affect vegetation, soil and air. Further changes could produce shifts in agricultural production among different domestic and international regions (Haney and Field, 1991).

## Definitions and Classifications of Pesticides/Chemicals

Control of pests through pesticides is called a chemical method (Hill, 1983). Hill noted that chemical control was mainly repetitive in nature and it was also a method where some predictable results could be gathered. Pesticide are defined by the Federal Environmental Pesticide Control Act as:

> (1) Any substances or a mixture of substances intended for preventing, destroying, repelling, or mitigating any insect, rodent, nematode, fungus, weed, or any other form of terrestrial or aquatic plant or animal life or virus, bacteria or other micro organism which the Administrator declares to be a pest, except viruses, bacteria or other micro organisms on or in living man or other animals, (2) any substance or mixture of substances intended for use as a plant regulator, defoliant or desiccant (Green, Hartley, and West, 1977, p. 294).

Green, Hartley, and West (1977) further stated that main groups of pesticides were herbicides, fungicides and insecticides. They also included minor groups of rodenticides, avicides (birds), molluscides, acaricides (mites), vematicides, bactericides and antivirals.

Hill (1983) noted that chemical application rarely kills all the pests and the few which survive usually soon give serious problems by the development of resistance. He classified insecticides from different modes of actions such as: (1) Repellents (to keep the insects away), (2) Fumigants (gases and smokes), (3) Stomach poisons (mixed with baits to encourage ingestion), (4) Contact poisons (absorbed through cuticle), which may be of two types: Ephemeral - short lived and Residual poisons (which remained active for a long time), (5). Systemic poisons (sprayed on plants or applied to the trunk), (6) Smokes (powders mixed with combustible material, and (7) Antifeedants (can be used for plant protection).

Rudd (1966) mentioned that a classification of chemicals used in pest control may be based on five groups: 1) Physical state includes solid, liquid, or gas. Solid refers to Dusts, Baits, Seed dressing, and Granules. Liquids are the common spray materials which include toxic substances in true solution (e.g. nicotine sulfate in aqueous solution); toxic substances in suspension refer to finely divided solid particles in very high volumes of water. Gases are toxic substances that are applied as gaseous fumigants, and toxic substances applied as solids but which volatize quickly; 2) Target groups include Insecticides, Herbicides, Acaricides, Miticides, Fungicides, and Rodenticides; 3) Purpose of application includes reduction in pest numbers (reduction control) and prevention of access. The extreme case of reduction is eradication. But eradication of well established species is difficult and expensive. However, hindering access to a crop site is usually done by physical means, for example: Trenches around fields to trap white fringed beetles. In such cases, chemical repellents are not widely used. Chemical pesticides may also be used to produce results discussed above under serial number 3 by directing at a link in a chain. As for example, mosquito control was performed to reduce transmission of malarial organisms; 4) Physiological action (manner of contact) includes stomach and contact poisons; 5) Chemical nature includes inorganic and organic chemicals.

The EPA (1990) defines pesticides as "chemical substances used to destroy, control, or repel undesirable organisms which may include plants, insects, fungi, nematodes, rodents, predators, or microorganisms" (p. 4). Cremlyn (1978) defined pesticides as chemicals designed to control the attacks of various pests on agricultural and horticultural crops.

Young (1987, p. 3) citing Mellor, and Ware stated that "a generally acceptable definition of pesticides includes key phrases such as chemical substance or mixture of substances intended for preventing, destroying, repelling, or mitigating any pests and substances intended for us as a plant regulator, defoliant or desiccant" (p. 3).

In the above paragraphs, various definitions of pesticides were provided. Detailed discussion on the uses of pesticides were also depicted in the subsection of this chapter title historical trends. The National Research Academy (1989) indicated that in 1940's the use of synthetic organic pesticides began with higher expectations. Trends of usages reflected that for the first time effective control of agricultural pests seemed to be possible.

Young (1987) further stated that in 1980 U.S. manufacturers produced 660 million kilograms (kg) of synthetic organic pesticides, valued at $4.2 billion. Five hundred thirty (530) million kg of pesticides were used in the U.S. to produce food, clothing, and durable goods (Young, 1987). This stood at 2 kg of pesticides per person. The retail value of the sale of pesticides in the U.S. was $5.8 billion during that period. Young (1987) contended that because of its immense benefits, there was an extensive demand for this product. He further pointed out that though the benefits of the proper use of pesticides were enormous, there were significant risks involved as a result of wide spread and intensive use of pesticides.

Pimentel (1979) noted that pesticides were used mainly against weeds, insects, and plant pathogens. Among these pesticides used annually, 51 percent were herbicides, 35 percent were insecticides, and 14 percent were fungicides. He further noted that "Of the food crops, only peanuts, lettuce, cole, potatoes, tomatoes, onions, cantaloupes, peppers, apples, peaches, oranges, grape fruits and lemons have more than 75% of their acreage treated with insecticides" (p.100).

A USDA report (1977) indicated that herbicide use increased very rapidly as compared with other pesticide use. So the rapid increase of herbicides not only increased in specialization and intensity of crop protection in general, but it also added risks to public health and the environment (Wilcott, Johnson and Long, 1991). Added to this was contamination of ground water with pesticides which became a great issue of growing concern. All these factors coupled with other health risks associated with pesticide residuals are likely to have an influence on thinking of alternative control methods to pesticides.

## Alternative Agriculture

> The contamination of our world is not alone a matter of mass spraying. Indeed, for most of us this is of less importance than the innumerable small-scale exposures to which we are subjected day by day, year after year. Like the constant dripping of water that in turn wears away the hardest stone, this birth to date contact with dangerous chemicals may in the end prove disastrous. Each of these recurrent exposures, no matter how slight, contributes to the progressive buildup of chemicals in our bodies and so to cumulative poisoning. Probably no person is immune to contact with this spreading contamination unless he lives in the most isolated situation imaginable. Lulled by the soft cell and the hidden persuader, the average citizen is seldom aware of the deadly materials with which he is surrounding himself; indeed he may not realize he is using them all (Carson, 1962, pp. 173-174).

Pesticides are generally considered by most farmers/users as an important and profitable input in the process of production (LaDue, 1979). But due to large scale use (misuse) many pests were growing resistant to pesticides (Food and Agricultural Organization, 1969). The tragedy was that when the resistance was suspected, the user often times was tempted to increase either the doses or frequency of application or both (Matthews, 1979; World Health Organization, 1990). This situation caused immense damage to the ecosystem which might lead to decreased agricultural production. The user also subsequently incurred more economic losses beyond the area of agriculture. These aggravating situations coupled with the issues of making the environment and ecology free from the harmful effects of pesticides, and consequently, sustainability of agriculture, as such, led to the more judicious application of pesticides. Further it may be noted that though resistance to insecticides was apparent for many decades, tolerance to fungicides is more recent (Matthews, 1977).

The foregoing developments associated with the use of pesticides necessitated the emergence of alternative agriculture to ensure real improvement of the quality of life of mankind as well as to make the world a safer place for future generations. In agriculture, control of pests will play an important role to alleviate world hunger, but while doing so, socio-economic and political factors must be identified (Perkins and Pimentel, 1980). Referring to the effects of pesticides, the World Health Organization (1990) in a report, contended that chemical methods were not the only methods of pest control, although the number of pesticidal active ingredients deliberately introduced to the U.S. environment exceeded 1,200 (Krummel and Hough, 1980). Moreover, it was not necessarily the best method (Pimentel ,1978). Pimentel noted that despite the use of 800 million pounds of pesticides, an estimated 30 percent of crops are damaged annually due to pests. The World Health Organization (1990) suggested that many other methods were used besides pesticides to control pests, which included: application of particular agricultural approaches; use of pest resistant crop varieties; and biological methods which involved the release of sterile insects or animals that destroyed the pests, not the crop. These methods may be termed as alternative methods of crop production.

Further, problems associated with the use of pesticides were manifold. There was no doubt that the continuous development of pesticides to control pests, modified and/or changed the socio economic progress of agriculture. Initially and up to the last three decades, impacts of pesticides were viewed only from positive sides. During that time, the socio economic changes which resulted due to the use of pesticides were seen as the natural result of a productivity increasing technology (LaDue, 1979). But at present public policy makers as well as scientists are also considering the negative externalities. Now average citizens are conscious and aware of the impending danger of pesticides in their day to day lives. Their conscious feelings, increased awareness of the negative externalities of pesticides, and especially the damages caused to human health and the environment accentuated policy makers decisions to cancel the use of many pesticides. This phenomenon undoubtedly lead them to find non-chemical pest control methods or techniques. The question or controversy over the use of pesticides continued unabated. Some argued that use of pesticides should be entirely discontinued (Sheets, 1979).

Moreover, the energy crisis also involved questions on benefits of pesticides versus non-chemical controls and effects on labor utilization (Tschirley, 1979). Tschirley's arguments were based on the declining reserves of fossil fuel energy. In the developed world like the U.S.A., agriculture used fossil fuel, a non-renewable resource in the form of fertilizers, pesticides, and energy to irrigate water as a substitute for land resources in the cultivated lands. Such external inputs will be necessary to attain high productivity "if and when additional marginal lands throughout the world are opened to cultivation. But rapid depletion of fossil fuel resources may well preclude their use for such purposes" (Tschirley, 1979, p. 5). All these issues coupled with the potential human health hazards related to pesticides, augmented an increased necessity to search for alternative methods of agricultural production. In this connection it may be noted that a survey of the Iowa Farm Business Association mentioned that 67 percent of the respondents indicated that pesticides threatened their health (Duffy, 1989). Along with this now comes a common question, what is alternative agriculture or alternative control method of agriculture?

The National Research Council (1989) defined alternative agriculture as any system of food or fiber production that systematically pursued the following goals:

> - more thorough incorporation of natural processors such as nutrient cycling, nitrogen fixation, and beneficial pest predator relationships into the agricultural production process.
>
> - reduction in the use of off farm inputs with the greatest potential to harm the environment or the health of farmers and consumers;
>
> - productive use of the biological and genetic potential of plant and animal species;
>
> - improvement in the match between cropping patterns and the productive potential and physical limitations of agricultural lands;
>
> - profitable and efficient production with emphasis on improved farm management, prevention of animal disease, optimal integration of livestock and cropping enterprises, and conservation of soil, water, energy and biological resources (p. 6).

Some also viewed "alternative agriculture as a generic term for farming with methods other than strictly conventional technology" (Madden, 1984, p. 23). Some authors also defined alternative agriculture in terms of organic or biological farming (Papendick, 1984), and advocated for non-chemical methods of pest control. In this respect Papendick mentioned that organic farming sought to reduce to a great extent or to avoid altogether, the use of pesticides, growth regulators, fertilizers and other agricultural chemicals. This system depended mainly on crop residue, crop rotation, animal manures, green manures, legumes and non-chemical pest control measures. These methods would help maintain tilt of the soil, supply nutrients and control insects, weeds and diseases, he added.

The foregoing discussions presented a philosophy on the issue of alternative agriculture to the major aspects of pest control. In the above, some definitions of alternative control methods were cited. However, more definitions on alternative agriculture are presented below. Benbrook (1991) viewed alternative agriculture " as the process of on-farm innovation that strives toward the goal of sustainable agriculture" (p. 3). He considered sustainable agriculture as a dynamic concept. He stated that "alternative agriculture encompasses efforts by farmers to develop more efficient production systems, as well as efforts by researchers to explore the biological and ecological foundations of agricultural productivity" pp. 3-4. He foresaw sustainability and alternative agriculture to go hand in hand, when he stated:

> Sustainability will always remain a goal to strive toward, and alternative agriculture systems will continuously evolve as a means to this end. Policy can and must play an integral role in this process (p. 7).

Cook (1991) defined alternative agriculture as:

> A process or strategy used to guide decisions with the goal of making the farming enterprise more sustainable both economically and ecologically. It is not a distinct set of farming practices, methods or systems. Moreover, there is no intrinsically correct way to proceed since different soils, climates and market requires different practices, methods or cropping systems. Nevertheless, the same general ecological principles can be used to guide the process, whether in a given field, on the farm, with a specific region, or across the United States (p. 62).

The National Research Council (1989) defined alternative agriculture as an integrated approach when it stated:

> Alternative agriculture is not a single system of farming practices. It includes a spectrum of farming systems, ranging from organic systems that attempt to use no purchased synthetic chemical inputs, to those involving the prudent use of pesticides or antibiotics to control specific pests or diseases. Alternative farming encompasses, but is not limited to, farming systems known as biological, low-input, organic, regenerative, or sustainable. It includes a range of practices such as integrated pest management (IPM); low-intensity animal production systems; crop rotations designed to reduce pest damage, improve crop health, decrease soil erosion, and, in the case of legumes, fix nitrogen in the soil; and tillage and planting practices that reduce soil erosion and help control weeds. Alternative farmers incorporate these and other practices into their farming operations. Successful alternative farmers do what all good managers do. They apply management skills and information to reduce costs, improve efficiency, and maintain production levels (p. 4).

The National Research Council (1989) further stated that some examples of practices and principles emphasized in alternative systems include:

> - Crop rotations that mitigate weed, disease, insect, and other pest problems; increase available soil nitrogen and reduce the need for purchased fertilizers; and in conjunction with conservation tillage practices, reduce soil erosion.
>
> - IPM, which reduces the need for pesticides by crop rotations, scouting weather monitoring, use of resistant cultivars, timing of planting, and biological pest controls.
>
> - Management systems to control weeds and improve plant health and the abilities of crops to resist insect pests and diseases.
>
> - Soil-and water-conserving tillage.
>
> - Animal production systems that emphasize disease prevention through health maintenance, thereby reducing the need for antibiotics.
>
> - Genetic improvement of crops to resist insect pests and diseases and to use nutrients more effectively.
>
> Alternative systems are often diversified. Diversified systems, which tend to be more stable and resilient, reduce financial risk and provide a hedge against drought, pest infestation, or other natural factors limiting production. Diversification can also reduce economic pressures from price increases for pesticides, fertilizers, and other inputs; drops in commodity prices; regulatory actions affecting the availability of certain products; and pest resistance to pesticides.
>
> Alternative farming practices can be compatible with small or large farms and many different types of machinery. Differences in climate and soil types, however, affect the costs and viability of alternative systems. Alternative practices must be carefully adapted to the biological and physical conditions of the farm and region. For example, it is relatively easy for corn and soybean farmers in the Midwest to reduce or eliminate routine insecticide use, a goal much harder for fruit and vegetable growers in regions with long production seasons, such as the hot and humid Southeast. Crop rotation and mechanical tillage can control weeds in certain crops, climates, and soils, but herbicides may be the only economical way to control weeds in others. Substituting manure or legume forages for chemical fertilizers can significantly reduce fertilizer costs. However, a local livestock industry is often necessary to make these practices economical (pp. 4-5).

In one sentence, alternative agriculture "is a systems approach to farming that is more responsive to natural cycles and biological interactions than conventional farming methods" (National Research Council, 1989, p. 135).

The League of Women Voters' Education Fund (1989) defined alternative agriculture as follows:

> An alternative agriculture system employs biological and cultural approaches to managing pests and building soil fertility. It involves crop rotations and planting of legumes (which reduce the need for nitrogen fertilizer) and often includes livestock as an integral part of the operation. Livestock provide fertilizer, consume crops grown during rotations and also can forage on fallow land (p. 10).

## Cultural Practices

The above discussion of definitions of alternative agriculture and its related issues also revealed that cultural practices like crop rotations along with other elements are important components of alternative agriculture. As is known, cultural practices refer to those regular practices that do not need the use of any specialized equipment or additional skills to control pests or prevent them from inflicting any economic loss (Hill 1983). Some good cultural practices would include: crop rotation; disease resistant and tolerant varieties; optimal growing conditions; correct time of sowing and harvesting; tillage; fallow and sanitation (Sherf and Macnab, 1986; Hill, 1983). Sherf and Macnab (1986) suggested that crop rotation could increase soil fertility and inorganic matters needed to be used in a rotation with alfalfa, clover and other legumes.

Studies indicated that Britain and mainland Europe formed the traditional base for agriculture from Roman times and beyond (Lampkin, 1992). Lampkin mentioned that these countries followed cultural practices and indicated that in the rotation, the presence of a ley helped soil fertility to be restored, especially from the view point of organic matter and nitrogen. Moreover, due to crop rotation the works of earthworms coupled with grass roots and other biological activity in the soil proved to have good effects on soil structure. Lampkin (1992) further demonstrated that the effects of crop rotation was higher yields and more productivity. In addition, if crop rotation was not followed then "soil slickers" - decline in yields due to monocultures would be inevitable.

However, benefits of crop rotations for environmental safety and increased yields are well documented. (Lampkin, 1992; Power, 1987; Heichel, 1987; Voss and Shrader 1984; Baker and Cook, 1982; Shrader and Voss, 1980; Heady and Jensen, 1951; Heady, 1948). It may be noted that although most of the benefits of crop rotations are common to all rotations, some other benefits vary by types of tillage, cultivation procedures, fertilization, and pest control methods followed in rotation (National Research Council, 1989). Rotational effects (i.e. increased yield of a grain crop compared to continuous cropping under similar conditions) existed irrespective of whether rotations included leguminous or non-leguminous crops. For example, Power (1987) indicated that if corn followed wheat, which was a non leguminous, it would produce higher yields compared to continuous corn if the equal amount of fertilizer was used.

Further, rotations were also considered as principal means to control insects, pests and diseases (Lampkin, 1992; Cook, 1986). Cook (1986) indicated that increased soil moisture, availability of nutrients and pest controls are the main factors which contribute to the rotational effects. Rotations also provide diversification. The National Research Council (1989) indicated that "Diversification provides an economic buffer against price fluctuations for crops and production inputs as well as vagaries of pest infestations and the weather" (p.141). Carry over of diseases and insects from one crop to the next and survival of soilborne insects and diseases could be reduced if the host crops were altered with non-host crops. So much is the necessity of crop rotation.

However, crop rotations are not the only way of controlling pests. Mixed or inter cropping (Lampkin, 1992) of one or more plant species (poly cultures) could also provide some effective control. Rotation is not a fool-proof system. As the National Research Council (1989) noted:

> Rotations may have their disadvantages however, particularly in the context of current government subsidies and requirements for federal government participants. Rotations that involve diversifying from cash grains to crops such as leguminous hays with less market value involve economic trade-offs. Adopting the use of rotations may also require purchasing new equipment. As with all sound management practices, rotations must be tailored to local soil, water, economic and agronomic conditions (p.141).

The above observations further evidenced that rotations, management/cultural practices, genetic improvements of seeds and pesticides are widely used to control pests in today's agriculture. In spite of that, expenditure on pesticides as an input were estimated to be 20 percent of total input costs. Use of herbicides accounted for more than 65 percent of the total pesticides (National Research Council, 1989). So if alternative controls could be practiced, farmers and society could benefit from more economic use of pesticides and live in a better environment. With this end view, it is emphasized that alternative controls should play a major role in shaping future agricultural systems. Of course that does not mean that right now there will be total discontinuation of pesticides (Boeringa, 1980). In this connection Boeringa (1980) stated:

> The total rejection of all synthetic chemical aids would be just as unrealistic as their excessive use is disastrous. Perhaps the criteria for their use ought to be that essential food requirements are threatened and not that the cost price otherwise would become too high. The choice of criteria is however a social rather than a scientific or technical problem (p.175).

Therefore, it is clear that the decision of adopting alternative agriculture depends largely on the consumers as well as producers (Boeringa, 1980). History, time and again has suggested that social and economic policy would only succeed if the same had a foundation related to sound ecological use of natural resources (Gardner et al., 1991). In that context the development of

Integrated Pest Management (IPM) as a system of alternative agriculture to safeguard the humans and nature is an outcome of historical incidence.

## Integrated Pest Management (IPM)

The history of pest management or control indicated that most of the development about conceptual origins of integrated pest management (IPM) to protect crops centered on the overuse and over reliance of chemical pesticides following World War II and their subsequent unfavorable consequences such as growth of chemical-pesticide resistant insects and plant pathogen populations, and the fast rising of target pest populations following treatment, emergence of secondary pests due to the killing of beneficial insects and detrimental environmental effects (Smith, Apple and Bottrell, 1976). However, the concept of Integrated Pest Management/control (IPM) passed, through different stages of development. Entomologists first articulated the concept of integrated control. They articulated ecological principles to utilize biological and chemical control methods against pests (Smith, Apple, and Bottrell 1976). Later on, it was extended to include all other control methods (Smith and Reynolds, 1965). Some authors proposed the idea of "managing" (not controlling) pest populations and propounded "pest management" over the term "integrated control". Now the pest management concept has extended to a wide horizon and includes all kinds of pests. That is why Smith, Apple and Bottrell (1976) remarked that pest management field now is commonly known as integrated pest management.

More steps for the development of IPM were initiated by the Federal government in 1972. (Hinkle, 1989; Smith, Apple, and Bottrell, 1976). Hinkle noted that IPM got a boost from President Nixon in 1971 when he transferred the authority from the USDA to the Environmental Protection Agency (EPA) to regulate pesticides.

In 1972, many pilot projects were undertaken to implement pest management projects. Smith (1978) also noted that the Huffaker IPM project, which originated from the Presidents' directive of a national project involving 19 universities, was the path-finder towards a new age of plant protection. It may be noted that the purpose of this review on IPM is to show a brief development of IPM. It is, however, beyond the scope of this discussion to bring a complete and detailed picture of IPM as such.

The objective of IPM is the optimization of control in terms of the overall economic, environmental, and social needs of mankind (Glass, 1975). Sustainability was an inherent theme for pest management and IPM was a synthesis of discrete management concepts in its commercially usable forms (Horton, Pfeiffer, and Hendrix 1991). Proponents of IPM believed that over reliance on any single method like synthetic pesticides was not an effective way to control pests if compared to a multiplicity of methods. From the viewpoint of pest control, IPM dated back to the mid 1950's. But credit for the origins of the concept might belong to entomologists like Stephen A. Forbes and C.W. Woodworth (National Academy of Sciences, 1975). Though there existed many definitions of IPM as practitioners, Perfect (1992) noted there was consensus on the major features of IPM. These included: "minimal use of synthetic pesticides, and maximum reliance on natural regulatory mechanisms to maintain pests below the level at which they cause economic damage. The approach is rooted in ecological thinking and despite its attraction, has been slow to move from theory to practice" (p. 47). Perfect (1992) further noted that breeding of crop resistant cultivars was the most important advancement to facilitate IPM.

Quoting the Food and Agricultural Organization (FAO, 1967), the National Academy of Sciences (1975) defined Integrated Pest Control as "a pest management system that in the context of the associated environment and the population dynamics of pest specifics, utilizes all suitable techniques and methods in as compatible a manner as possible and maintains the pest population at levels below those causing economic injury" (p. 381).

The main theme of this definition was that a conventional pesticide should be used if economic injury thresholds would otherwise be exceeded (National Academy of Sciences, 1975). However, IPM as perceived by the National Resource Institute (1992) needed to be considered as a subset of crop management. The core of IPM was but the development of guidelines (set) of practices to control pest populations at a level (threshold) beyond which would cause significant economic loss (National Resource Institute 1992) and emphasized minimal use of synthetic biocides. The institute further viewed IPM as non-prescriptive, meaning that the practitioner must have at his/her disposal a set of appropriate technologies and accordingly he/she could have a choice to solve the problem.

Hoy (1989) pointed out, quoting Glass (1976), that plant resistance, cultural, biological, chemical, use of insect pheromones, plant growth regulators, quarantine, monitoring, eradication, regulation, and use of insect pheromones formed tactics in IPM.

The preceding discussions indicated that, as a matter of fact, IPM is a subset of alternative control practices which could have its union with sustainable agriculture. However, it was well documented that to develop an IPM system, knowledge of the agro-ecosystem, pests, relationships between the pests and beneficial species and local system of cultivation was needed (Bergman and Tingy, 1979; Levins, 1986).

Pfender (1989) put much emphasis on cultural methods for control of plant diseases in IPM. While doing so, he recommended quantifying costs/benefits of cultural control because this was necessary to establish economic thresholds. However, Pfender (1989) mentioned that cultural controls in IMP were also beset with some problems, and stated:

> The application of the threshold concept to cultural control methods presents some unique problems. In contrast to pesticides, which are usually applied near the time of their intended effect, cultural controls are generally applied to affect processes

> that occur after a considerable time delay. This time delay, and the central importance of environmental modification to many cultural controls, introduces a larger element of unpredictability to the quantitative effects of these methods, making predictive threshold determinations difficult at best (p. 65).

Beside the shortcomings, in general, IPM could help lower the quantity of pesticides used (Shoemaker, 1989). In her research on integration of environmental concerns into IPM programs she focused on development of site specific pesticide programs. This could be done by considering local conditions for soil characteristics, level of insect resistance, hydrogeology and climate.

Messenger (1970) in a study of bioclimate inputs to biological control and pest management programs found that one of the potential factors for success of a biological control agent, which was a component of IPM, depended on climate. The study vividly pointed out how climate affected pests, natural enemy establishment, success of biological control, economic injury levels and economic thresholds, and effectiveness of integrated pest management. This study was done in California. The author however, suggested that local crop climate could be modified to some extent, increase crop production, reduce attacks of pests or modify natural enemy effectiveness. The authors' suggested measures were:

> Irrigation (via furrows, flooding, or overhead sprinkling), shading, cultivation, orchard heating in winter (smudging), temperature control through induction of air turbulence (blowers, helicopters), windbreaks, and hedgerows to moderate wind speed, strip cropping and plant spacing (p. 98).

This study suggested the importance and necessity of considering bioclimatic inputs to pest management programs such as IPM. He emphasized that climate is a major agent and principal participant in a given agro-economic system.

In another study Willey (1978) suggested that the application of IPM had four preconditions: 1) A specific crop/pest IPM technology should be available. Specific technologies would include pheromones, beneficial species, detection and sampling methods, and narrow spectrum pesticides; 2) IPM application required scientific information on pest and beneficial species; 3) An IPM practice was needed such that the technology and information be objective based on the practitioner; 4) Application of IPM must not have unacceptable economic loss to the adopter. In this respect the author indicated that in theory IPM advocated a reduction in pesticides, but needed "factor substitution", i.e. the use of other inputs such as labor. She advocated that a detailed study was needed to determine the yields and costs arising from IPM. Moreover, Willey (1978) mentioned the statistical and economical problems to determine the yield and cost of IPM practices. "Obviously, the economic performance of IPM cannot be measured until sufficient diffusion has occurred" (Willey, 1978, p. 287).

But whatever may be the arguments, one thing is sure: use of pesticides created many social problems; and disrupted and complicated the stability of pest species in our agro ecosystems (Glass, 1976; Furtick, 1976).

## Economic Importance of Alternative Agriculture

The foregoing analysis on the damaging effects of pesticides and subsequent attempts to mitigate further deterioration testified to the importance and widespread adoption of alternative agriculture. In this context at present, plant protection specialists throughout the world were facing a challenge to integrate pest control measures effectively. But, these measures must be selected based on environmental friendliness, cost effectiveness, and sustainability (Kadir and Barlow, 1992).

Further, to adopt alternative control, though the current literature demonstrated methods with less dependence on pesticides to reduce health, environmental, and ecological hazards, it is believed that the most of the farmers would also consider economic benefits in the first place. Because whatever beneficial effects a system might have would ultimately be futile if it was not economically viable. Various studies (National Research Council, 1989) documented that the adoption of alternative control measures in several cases proved to be as profitable as conventional methods and supported the economic viability of alternative practices, control measures and or systems. The National Academy, however, singled out IPM "to have been very successful in many instances" (p. 241).

Whitten (1992) disclosed that the Dutch Government in its multi year crop protection plan set a target of pesticide reduction by 50 percent before the year 2000. A similar policy was being implemented in other EEC countries. Further, Zadoks (1989) cautioned that in the Netherlands high input/high output agriculture was economically possible only in the short run. This was possible because of the subsidies the tax payers bore in many phases of agricultural production, storage and exports. In this respect, Whitten (1992) pinpointed that the position of the U.S. was not dissimilar to EEC countries. Quoting the National Research Council (1989), he reported that direct and indirect subsidies by tax payers and unsustainable production systems featured North-American agriculture in the twentieth century. He, however, observed that as a step for giving more importance to alternative agriculture the U.S. began to recognize the need and importance for a rapid change of her approach to agricultural production, although the U.S. had the best access to sophisticated pest management technology.

The former Soviet Russia used 250,000 to 300,000 tons of more than 300 pesticides on 170 million hectares in 1989. This pesticide usage accounted for 5.3 percent of worldwide usage (Whitten, 1992). But the irony was that forty species of arthropod and fungi appeared as resistant to one or more pesticides. Moreover, in 1989, 5.7 percent of food stuffs were contaminated with pesticides. He also mentioned the serious negative effects the former Soviet Russia was facing due to pesticide use such as: destruction of ecosystems, pollinators, natural enemies, wild animals and birds and environmental pollutants. The negative externality for biological control was, however, less than for pesticide usage (Whitten, 1992).

According to Pimentel (1978), in the U.S. the external cost of pesticide use was estimated annually to be at least $3 billion excluding money costs of the estimated death of persons. In addition, some pesticides are carcinogenic (Pimentel, 1978, Environmental Protection Agency, 1979). Those carcinogenic effects were not included in the $3 billion cost of pesticide usage.

All these facts further suggest that the economic importance of alternative agriculture as a pest control measure cannot be under estimated.

If the future American generation in particular, and the world population in general, wants to live a more healthy life, then perhaps, alternative control measures for agricultural productivity is a right path to follow. This is justified from both the economic and social points of view. This is economically desirable because such practice will use less pesticide and this is socially desirable because it will reduce agricultural pollution and improve the environment. Such a process, however, needs an all-out effort from producers, processors, and consumers, as well as policy makers. In the present scenario, the main actors are the producers/farmers and the consumers. But above all, Federal Government is a major actor in formulating and implementing a policy measure about alternative agriculture. To make this program a success it is very important to make all the parties involved in agricultural production, distribution, and consumption more conscious about alternative control methods through education, and knowledge. That is a first step to follow.

## Place of Agriculture and Need of Further Knowledge, Education and Extension

Currently about 2 percent of the total U.S. gross national product (GNP) comes from agriculture. But the production, processing and sale of food and fiber comprise 17 percent of the total GNP (National Research Council, 1989). Though less people are employed in agriculture, the U.S. is still the major producer and exporter of agricultural commodities. The U.S. is considered as the bread-basket of the world. However, according to the Oklahoma Department of Commerce (1988), agriculture contributed to 16 percent of the gross state product and 23 percent of the state's employment; so agriculture is considered as a major contributor to the economic base of Oklahoma.

This has been possible due to the publicly supported research programs for producing more food, obtaining required resources for agriculture, and improved marketing and delivery systems. In this respect dissemination of knowledge through U.S. "Land Grant" universities and the U.S. Department of Agriculture played a pivotal role (Finley and Price, 1994). Now with that past history in mind, knowledge of alternative agricultural education should be carried to the producers through various individuals like extension agents, local community leaders, students and youths, especially agricultural students. This scenario adequately addresses the need for an effective extension system to teach alternative practices.

Successful research results at the various levels of alternative agricultural systems obtained by the agricultural scientists, or others involved in this process will not be effective unless these are effectively communicated to the practitioners at the farm level. Therefore, farmers' knowledge should be updated, and they should be convinced that the alternative control methods will be beneficial to them from economic, social and environmental viewpoints. In this respect Vorst (1990) mentioned the necessity of further education in conventional as well as sustainable agriculture. Educational emphasis must also be placed on management aspects because knowledge of management is an important tool for success in one's business. But while emphasizing management, one must not forget that farmers who take part in the management process have some kind of perspectives and attitudes which speak of their own distinct cognitive styles (Lanyon, 1991).

Farmers like any other students of economics know that the demand for all food by the individual consumer is highly inelastic i.e., average consumer increases his total intake of food very little when the retail price of food falls and vice versa. So all farmers must take what the market settles for them through a price level or they must adjust their production to the glacier like movement of aggregate market demand. This supports that farmers should have intelligent decision making and management processes and understand well the consumers' demands. All these aspects need to be emphasized in the education of the farmers in alternative control methods. Without that understanding, no policy action will be successful. However, it needs to be mentioned that in the U.S. Federal policy responded to the farmer's needs in times of situations like high per acre yield goals, surplus production capacity, ever increasing foreign competitions, and environmental considerations (National Research Council 1989). But profitability in farming in the 1990's is not as it was in the 1970s. Moreover, U.S. agricultural capacity is growing faster than world markets are expected to grow (Edwards, 1985). Not only that, if U.S. farmers are to expand their markets through exports, then their real prices received for export commodities will gradually be lower to be competitive (Edwards and Harrington, 1984).

The Situation since 1990 has not improved that much. In 1986, value of agricultural exports fell to $26 billion from $43 billion in 1981. In 1987 it increased to $28 billion (National Research Council, 1989). If that is the scenario, then a question arises as to the justification of increasing higher productivity through pesticides, fertilizers and other chemicals. All those things need to be well understood by the farmers. A well developed information and education system to communicate with the farmers is of utmost importance. However, these are broad policy issues which should be understood by all conscious farmers through an effective educative process.

The good news is that "One of the strengths of the U.S. agriculture is the willingness of farmers to adopt proven alternatives. This constant evolution and adoption of new practices has helped the United States become a global leader in agricultural research, technology, and production" (National Research Council, 1989, p. 25).

Therefore, it appears that extension knowledge and education to the farmers will help them adopt alternative farming quickly. So, farmers need education, knowledge, and enough information on alternative practice to make the program a success. In this context Oklahoma State University (OSU) Cooperative Extension Service can play a major role to educate the farmers. In this respect Senator Stipe and Lewis's (1989) report to the House of Representatives emphasized that "OSU Cooperative Extension should continue to develop, expand and provide knowledge in farm management, alternative agricultural enterprises and similar projects" (p. executive summary, no page number was written).

The National Research Council (1989) rightly mentioned that alternative farming was not easy when it stated:

> Alternative farming practices typically require more information, trained labor, time and management skills per unit of production than conventional farming (p. 9).

This statement itself spoke about the necessity of further knowledge, research and education in alternative agriculture. The National Academy further contended that there existed little research towards many on-farm interactions essential to alternative control methods in agriculture which included crop rotations, tillage, pest control and nutrient cycling. Enthusiastic farmers would always develop and adopt some alternative methods through education and extension process. With a network of county extension agents and other specialists such as IPM specialists, Land Grant Universities can play a vital role to educate farmers on the impact of alternative agriculture. These education programs should aim at integration of pest control methods and economic aspects of management (Ward, 1991).

## Greens and Spinach

Turnip (*Brassica campestris rapa rapifera*), Mustard (*Brassica juncea, Brassica nigra*), Collard (*Brassica oleracea var.* ), Kale (*Brassica oleracea*) and Spinach (*Spinacia oleracea L.*) are cruciferous leafy greens. Greens are considered cool season crops and they grow during the spring and fall seasons. They constitute important commercial and garden crops in the Southern United States (Sumner, Glaze, Dower and Johnson, 1978). Among the vegetables used as greens, spinach is the only green of major commercial consequence (Halfacre and Barden, 1979).

For fresh market supply, most of the spinach is hand harvested, while for processing it is mechanically harvested (Correll et al. 1994; Sumner, Glaze, Dower, and Johnson 1978).

## Spinach (*Spinacia oleracea L*)

Spinach is a cool season, long day, short night plant. According to Edmond, Senn, Andrews and Halfacre (1975), spinach is the most important vegetable crop in greens. Spinach belongs to the family of Chenopodiacea or goosefoot family (Work and Carew, 1955). Spinach is grown as a direct seeded crop (Correll et al. 1994, Halfacre and Barden, 1979).

Planting and management strategies of spinach products are dictated by the market destination of the commodity. While spinach, which is direct seeded, grows very fast under sunny conditions, greens have their high growth at a low temperature, and "moderately deep, friable, highly fertile soils" are suitable for them (Motes et al. 1991). Spinach grows year round in California. In Oklahoma spinach is grown thrice: spring, fall, and overwinter (Motes, 1994, personal communication). Spring planted spinach and mustard crops are very likely to have a seed stalk (bolt). This in turn makes the crops less attractive in the market (Motes et al., 1991).

Bolting is accelerated by long days and also more prominent in certain cultivars (Halfacre and Barden 1979). However, some selected varieties may help reduce bolting (Motes, et al., 1991). If planting is delayed, it will aggravate bolt. According to Halfacre and Barden (1979), spinach got its widespread use in the U.S. over the last 75 years. They mentioned that about 84 percent of the U.S. spinach crop was processed and California produced about 57 percent of the processing spinach. Among the fresh market spinach, the share of California (year round) attributed to 47 percent, Texas (fall and winter) 26 percent, and the rest is supplied from the Mid-Atlantic states in the spring, and from Colorado in the summer. Work and Carew (1955) found that during 1955 Texas grew (on ten year average) about half of the 80,000 acres grown each year in the U.S. California, Oklahoma and Arkansas followed.

Brewer (1956) conducted a survey of vegetable production and marketing in Eastern Oklahoma. He found that there was a 54 percent decline in the acres of vegetable crops in the Arkansas River valley area (Eastern Oklahoma) from 1949 to 1954. This result pertained to a survey on selected crops, snap beans, spinach, sweet corn, and watermelons. He noted spinach to be more frequent than any other vegetable. The total acreage of spinach on the farm surveyed was 3,681 acres. However, field peas represented the largest crop enterprise having 2,135 acres. Next to this was greens.

Brewer (1956) mentioned that in that area, the processing market was the most important market for the vegetable producers. The producers sold 73 percent of the vegetables to the food processors and the rest (27 percent) was marketed in the fresh market. Walker, Wiggans and Pogue (1962) found that 15 percent of spinach was sold in the fresh market and 85 percent was sold in the processing units. Motes (1994) and Damicone (1994) noted that in Oklahoma, more than 95 percent of the greens and spinach are marketed through processors. Motes, et al. (1991) mentioned that buyers (i.e. processors) who contract greens for processing designate the variety to be grown. The field person ensured that quality and all legal aspects were maintained.

Spinach is very popular with the Americans. It is interesting to note that spinach ranked third among frozen vegetables and a survey of children in New York indicated that during 1955 spinach was their favorite vegetable (Work and Carew 1955). It is not known whether spinach is still popular to the children.

However, diseases and insects damage the economic value of spinach. Work and Carew (1955) mentioned damping off, downy mildew, leaf mold or blue mold and mosaic or yellows as main diseases which infect spinach. Warm, wet weather cause these diseases. These diseases could be controlled with copper oxide. Downy mildew, leaf mold or blue mold caused by *peronospora spinaciae* would accelerate in wet weather coincided with cool nights. Work and Carew (1955) did not favor use of copper. However some authors recommended prickly seeded, flat leafed varieties to be somewhat resistant to these diseases. (Scott, 1935; Virginia Truck Experiment Station, bulletin no. 57, and Cornell Experiment Station, bulletin no. 694). A viral disease of spinach, mosaic or yellow often known as blight carried by aphids could be controlled by resistant varieties like Virginia Savoy (Work and Carew, 1955). Similarly, for insects such as leaf miners which were maggots of flies, no good controls were known. Aphids, which caused damages to spinach and carried Mosaic, could be controlled though parathion or nicotine dust.

### Kale *(Brassica oleracea var. acephala)*

Kale develops very large green leaves. These leaves are used as greens (Edmond, Senn, Andrews and Halfacre, 1975). Kale varieties vary in shade of green of foliage (such as grass green and gray green), indentation of the leaves (i.e. indented and smooth) and plant height (dwarf and tall). Kale was known to the Greeks and Cato mentioned it in 200 B.C. (Ware, 1937). Kale is a cabbage like, winter-hardy plant (Ware and McCollum, 1980) grown for its much curled and succulent leaves. Kale is also called curly kale and Chinese kale (Nonnecke, 1989). Kale is an all year round but principally a cool season crop. Real merit of kale is as a cooling weather green. It works well if planted in late summer for fall and early winter use. (Ware 1937; Ware and McCollum, 1980). Ware and McCullan (1980) indicated that the commercial acreage of kale came down from 2900 acres in 1939 to 1000 acres in 1969 when estimates were discontinued. Ware (1937) mentioned two types of Kale grown in the U.S. such as Scotch and Siberian. While the Scotch is curled and has crumpled foliage of a grayish green color, Siberian is less crinkled and is bluish green. Virginia was the leading state in the production of kale. He also noted that with the more availability of refined vegetables in all seasons, kale was facing high competition. But still it is a favorite plant throughout the south for the production of winter greens. Kale is extensively grown in the Norfolk area of Virginia. For producing Kale and Collards, "the best production medium is heavy soil containing high organic matter with a good reserve of moisture" (Nonnecke, 1989, p. 406).

Collards (*Barassica oleracea var. Virdis*)

Collards are crops of cool season and they are winter hardy in regions having the first frost. The edible portion of the plant is the immature leaves. Collards are also known as bore cole, green cabbage, curly greens, narrow cabbage, and cole works (Nonnecke, 1989). Nonnecke (1989) mentioned that Collards have been known for at least 4000 years. Collards develop heavy fleshy leaves. They are used for greens (Edmond, Senn, Andrews and Halfacre, 1975). They can stand summer heat better than cabbage. If a cabbage crop would fail, then collards are also grown in its place (Hoover, 1971). Seeds of collards may be sown in the spring or in the fall. They may also be sown in seedbeds and transplanted to the field.

Georgia or Southern, Green Glaze, Morris Heading, Vates, Blue Max, and Champion are important cultivars of kale. Among these Motes et. al. suggested Vates, Georgia and Champion for Oklahoma. Collards suffer from the same pests and diseases as other *Brassicas*. Collards are a rich source of vitamins A and C and minerals (Sanders, 1988a). According to Sanders (1988a), it is one of the most popular garden vegetables in the South and now it is becoming a delicacy in the North. Seeds of collard may either be sown in the seed beds in the spring or the fall or transplanted to the field. Spacing of collards as Sanders (1988b) suggested depended on how the crop would be produced. They need to be spaced 10-15 inches apart if the plants are cut when half grown. On the contrary if they are harvested at full grown stage, then spacing 15-18 inches apart is needed. Deep cultivation is not desirable for collards. During summer and fall a rigid control program is needed. Above all, rotation is very important.

Mustard (*Brassica Juncea, Brassica nigra*)

Mustard is a half hardy annual herb (Ware, 1937). It is a quickly growing plant and produces seeds quickly. They are rich in vitamins and minerals. One half-cup of cooked mustard gives 11,000 units of vitamin A, 138 milligrams (mg) of vitamin B, 9.1 mg of iron, 12 mg of vitamin C, 291 mg. of calcium, 84 mg of phosphorous, 25 calories and 2 grams of protein (Porteous, 1971). Ware (1937) mentioned that White London, Giant Southern Curled, and Ostrich Plume were widely used varieties in the South. Similarly Chinese Broad Leaf, Florida Broad Leaf and Tender Green (Sanders, 1988b) were also extensively used varieties.

Mustard is sown early in the spring for use as a spring crop and in the fall for the winter harvest. The yield of mustard depends on the size to which it is grown, the length of cool season, and the number of cuttings. However, successive plantings are necessary for continuous harvesting of crops (say every 10 days in early spring for spring and in fall every two weeks are necessary). Porteous (1971) indicated that mustard was almost free of insects and disease.

## Turnip Greens (*Brassica rapa*)

Turnip greens are very valuable from the point of vitamins A and C in the greens and K in the roots. Turnips are biennial, fast growing (40-75 days) cool season plants (Nonnecke, 1989). They are grown in the spring, fall or winter in the South and early spring or fall in the North. Turnip green varieties mainly differ in color and shape (Rutledge, 1982). Purple Top, White Glove, Shogoin, Golden Ball and Just Right (Nonnecke, 1989) are the main varieties. Just Right is a hybrid fast growing suitable cultivar for the fall season. Just Right variety also gives a good greens crop in the spring (Rutledge, 1982).

A moist, well-worked and firm seed bed is necessary for turnip greens. Spacing of rows should be 18 to 24 inches apart between rows and 3 to 4 inches in the row (Nonnecke, 1989; Norris, 1971). Aphids, Caterpillars, and Flea beetles attack the foliage of turnip. Wire worms and Flea beetles larvae attack turnip roots (Rutledge, 1982). If planting is done in rows, cultivation to remove weeds from turnip is possible (Rutledge, 1982). On the other hand, if turnips are seeded for roots, it is rather impossible to cultivate them (Rutledge, 1982). Rutledge (1982) mentioned Downy mildew, and Alternaria leaf spot as main diseases of turnip greens . He, however, considered them not to be a major problem because they could be easily controlled. Motes, et al. (1991) developed a guide line on greens production in Oklahoma. From his report, yield, varieties (Table II), and planting dates (Table III) on greens production are reproduced. Thereafter, discussion is also drawn from that paper.

TABLE II

GOOD YIELD OF GREENS GROWN IN OKLAHOMA

| Greens | Processing | Fresh Market * |
|---|---|---|
| Spinach | ** 6 to 8 tons/A | 500 to 650 bushels/A |
| Turnip | ** 6 to 12 tons/A | 500 to 1000 bushels/A |
| Mustard | ** 8 to 10 tons/A | 500 to 800 bushels/A |
| Collard | 8 to 10 tons/A | 500 to 800 bushels/A |
| Kale | 8 to 10 tons/A | 500 to 800 bushels/A |

* 22 to 25 pounds per bushel.
** Additional harvests can produce an additional 4 to 5 tons/A each.
A=per acre

Source: Motes et al., 1991, p. 6031.1

Varieties

Spinach (35 to 45 days) Savory Supreme, Chesapeake, Hybrid No. 7 America (long standing), Grandstand, Ozark, Green Valley, Iron Duke, Fall Green, Kent, Coho.

Turnip (45 to 50 days), (for greens only) Improved Crawford, Alltop, Seven Top and Shogoin; (for greens and roots) Purple Top White Globe, Just Right (white).

Mustard (50 to 55 days) Slobolt, Southern Giant Curled, Florida Broad Leaf, Tendergreen.

Collard (75 to 85 days) Vates (good cold tolerance, long standing), Champion, Georgia (bunching).

Kale (45 to 55 days) Vates, Improved Siberian. Buyers contracting greens for processing will designate the variety to be grown. (Motes et al., 1991 p. 6031.1).

TABLE III

APPROXIMATE PLANTING DATES FOR GREENS GROWN IN CENTRAL OKLAHOMA

| Greens | Spring Crop | Fall Crop | Over Wintered Crop |
|---|---|---|---|
| Spinach | Mid January to late March | September to late October | November and December |
| Turnip | Early March to May 1 | September to early October | None |
| Mustard | Mid March to May 1` | September to early October | None |
| Collard | Mid March to mid April | September | None |
| Kale | Mid March to May 1 | September to early October | None |

Source: Motes et al. (1991), p. 6031.2

In Oklahoma, aphids, cabbage loopers, diamondback moths, imported cabbage worms, and army worms are common insects for greens (Motes et al., 1991). Foliar disease such as alternaria leaf spot, and blackspot (*Alternaria spp.*), cercospora leaf spot (*Cercospora brassica*), downy mildew (*Peronospora parasitica*), and white spot (*Pseudocercosporella capsellae)* are major diseases of the greens. The most harmful and frequent bacterial disease is black rot (*Xanthomonas campestris pv. Campestris).* Downy mildew or blue mold (*Peronospora Spinaciae*) and white rust (*Albugo occidentals*) are fungal diseases of spinach. Spinach is not commonly attacked by virus but collards, mustard and turnip are. *Fusarium.* Spp, *pythium* spp., and *Rhizoctonia solani* cause damping off to all greens. Phytophthora root, and crown root (*Phytophthora spp.*) and root knot nematodes (*Meloidogyne spp.*) affect the roots of the greens.

## Control Measures for Pests

Motes et al. (1991) noted that the method of managing pests of greens depended somewhat on the crops' intended uses. Fresh market greens, as for example, could tolerate little damage to the foliage, whereas the main concerns for processed greens is the contamination of the product with insects. Environmental factors such as rainfall, natural control from parasites and predators may help manage insects such as aphid populations (especially in fall crops). However, these parasites also appear as a potential contaminant for processing greens. Since wild mustards accentuate the presence of cabbage aphids and help their colonization in the greens, these weeds serving as hosts should be destroyed before planting greens. Scouting fields twice a week should be done to take remedial measures.

It was discussed before that processors were the main buyers for these greens; it was also noted that they set the quality standard and expected the producers to follow certain norms regarding their cultivation and treatments. In this respect, Willey (1978), noted that for vegetables and fruits market grading systems imposed serious constraints on the growers' ability to incur certain kinds of damages. The problem of cosmetic uses of pesticides posed a serious controversy and concerns, because "cosmetic use" did not improve yield or nutrition value. However, whatever may be the arguments, it is very important that these greens need to be protected or controlled from the attacks of pests. A quality disease free product was necessary to have a good market for vegetable production (Johnston, 1991; Motes, et al., 1991). Johnston (1991) indicated that despite the availability of resistant varieties, use of fungicides were needed; because either the diseases were not resistant to the variety or disease pressure was very high leading to lower yield. Johnston (1991) in his report on the National Agricultural Pesticide Impact Assessment further noted that the potential loss of EBDC fungicides would pose a problem to the effective control of vegetable diseases. EBDC and chlorothalonil possessed broad spectrum effects which minimized the possibility of developing pathogens resistant to them. But dicarboximides, metalaxyl and triadimefon, the short spectrum fungicides though considered to be very effective to control certain diseases, were likely to develop pathogens resistant to them. This resistance to fungicides was inevitable if they were used alone consistently. As such, the short spectrum fungicides were formulated or used with EBDC or chlorothalonil.

Motes et al. (1991) suggested the use of pesticides in Oklahoma as prescribed in Oklahoma State University (1994 )Extension Agents' Handbook of Insects, Plant Diseases, and Weed Control (E-832).

## Related Research

Perhaps all the discussions as set forth above lead to the point that the use of pesticides as such chemical control of pests needs to be curtailed. There exists many research studies which testify to the potential success on the reduction of pesticides to control pests. Pimentel (1993) conducted a study on reducing pesticide use through alternative agricultural practices. He first gave an account of the use of pesticides in the U.S. Then he discussed alternative control practices. As mentioned by Pimentel (1993), the use of pesticides in the U.S. grew 33-fold since 1945. He indicated that out of the estimated 434 million kg of pesticides used annually in the U.S., an estimated 320 million kg of pesticides were used by farmers to apply to agricultural crops in the U.S. Moreover, biological control and other cultural control methods were also used to combat pests. The loss of all agricultural production was still 37 percent which annually cost about $4.1 billion. Returns on every $1.00 invested in pesticides usage (as a direct benefit) to the farmers varied from $3.00 - $5.00 (Pimentel et al., 1979). According to Pimentel (1979), if pesticides were withdrawn, an estimated $8.7 billion or 9 percent increase in crop losses including additional costs of employing alternative controls would happen. As noted before, he estimated the cost of pesticide usage, which includes application and materials to be about $2.2 billion. From this figure he found the return per dollar invested on pesticides to be about $4.00.

Pimentel (1993) documented that pesticides were applied at various rates. On average 3 kg/ha was applied to 114 million hectare. This constituted about 62 percent of the 185 million hectare that were planted in the U.S., indicating that 32 percent of crops received no pesticides.

He reported that despite the increased use of pesticides over the last four decades, crop losses did not exhibit a concurrent decrease. Report of the survey data collected from 1940 to 1992 showed that losses from weeds fluctuated and declined to 12 percent from 13.8 percent. Pesticide application was distributed with a wide range among all crops: 93 percent of all row crops hectares and less than 10 percent of forage crops were treated with some pesticide. Herbicides were used in more than 90 million hectares in the U.S. The fact that crop losses were substantial in spite of the increased use of pesticides, evidenced that application of available alternative methods to pesticides would reduce its use. As an alternative strategy, he referred to scouting as an improved pesticide use technology.

Pimentel (1993) documented favorable results of alternative control methods for twenty two crops: wheat, rice, peanuts, sorghum, sugar beets, tobacco, alfalfa hay, cole, potatoes, tomatoes, sweet corn, onions, cucumbers, beans, sweet potatoes, apples, peaches and plums, oranges, grapefruits and lemons, pecans and other nuts. In almost all cases using a suitable combination of rotation, scouting, mechanical cultivation, cover crops, timing of cutting/harvesting, resistant varieties, spot treatments, black plastic mulch (for tomatoes but more expensive than herbicides, however, it results in earlier production), mowing, tilling and hand weeding. He calculated that the use of herbicides could be reduced to 33 - 80 percent without sacrificing yields. The most important finding from Pimentel's (1979) research was that a 9 percent decrease in production due to withdrawal of pesticides would cause an increase in the farm product value of about 36 percent. He pointed out that this increase would occur because demand for agricultural products is inelastic (has a low level of elasticity with respect to quantity). He found that for every 1 percent decrease in quantity of farm products, a corresponding 4 percent increase in price value would result. The overall impact, however, would be an increase of retail prices by 12 percent. This is so because the farm price represented 33 percent of a retail value of a food product.

Chambers and Lichtenberg (1994), using econometric methods conducted an experiment on pesticide productivity. At the beginning they stated that data bases on pesticides hinged critically on productivity issues. They contended that the extent on which pesticide use should be curtailed depended partially on the extent of how much food and fiber production would fall. They criticized the present information on pesticide analysis to be inadequate. Analysis of demand, they indicated, depended on "expert" assessments on informations about alternative production systems and change in crop damage.

The main defect of the assessment system is that it did not estimate marginal productivity (it estimated average). Adjustment by individual farmers was not considered. It was politically biased and proved wrong in retrospect. Following the model of Lichtenberg and Zilberman (L-Z) to estimate pesticide technologies as "damage-control" agents, Chambers and Lichtenberg (1994) developed a multi-output process (model) of the L-Z damage control technique. They applied this model to an aggregate data set of U.S. Agriculture. They conducted this research using an aggregated time series data set from 1949-90 for agricultural production sector in the U.S. including both crops and animal products.

As share of animal products were falling over time Chambers and Lichtenberg (1994) made an assumption that pest damage to animal products was insignificant and approximated that all pesticides were used for crop management. On the basis of that assumption, they found the following results: During the early 1950s, crop damage was 15 percent; crop damage was falling steadily with the use of pesticides and reached to 11 percent in the mid 1960s; and in the mid 1970s it was 6 percent; and it was stabilizing at 3 percent from 1979 through 1990s.

Though the research findings of Chambers and Lichtenberg(1994) may not be generalized for use in individual crops in each area of the U.S (because their analysis used time-series data for the entire U.S.), it focused on one important aspect indicating 3 percent crop loss. If this is so, it can be argued that alternative practices which included cultural practices and use of less pesticides that gained importance from the 1970s were a success. In the 1960s and 1970s there were more uses of pesticides but still losses were higher. But now less amounts of pesticides were used and the losses appear to be low. In this context Pimentel (1979) noted:

> Although seldom appreciated because of the publicity given pesticides, non-chemical control methods are used more extensively to protect crops from pests than are pesticides. Non-chemical controls for insect control are employed on about 9% of the crop acres, compared with only 6% treated with insecticides. For control of plant disease, non-chemical control is used on 90% of the acreage, compared with less than 1% treated with fungicide. Mechanical weed control is used on an estimated 80% of the crop acreage, while about 17% is treated with herbicides (p. 132).

The researcher would further cite site empirical findings in support of the above statements. Young (1987) indicated that for production of food, clothing and other durable goods, 530 million kg of pesticides were used in the U.S. in 1980. The annual use of pesticides declined to 500 kg by 1985. Citing a figure from the Council on Environment Quality, Young (1987) documented that there was a downward trend of insecticide uses in the U.S.A. from 1964 to 1982 (Table IV). But production of agricultural commodities did not decline during that period.

TABLE IV

PESTICIDE PRODUCTION IN THE U.S. IN MILLION POUNDS

| Year | Herbicide | Insecticide | Fungicide | Total |
|---|---|---|---|---|
| 1960 | 102 (15%) | 366 (57%) | 179 (28%) | 648 |
| 1965 | 263 (30%) | 490 (50%) | 124 (14%) | 877 |
| 1970 | 404 (39%) | 490 (50%) | 140 (13.5%) | 1034 |
| 1975 | 788 (48%) | 660 (41%) | 155 (9.7%) | 1603 |
| 1980 | 806 (61%) | 506 (34%) | 156 (10.0%) | 1648 |
| 1985 | 756 (61%) | 370 (30%) | 108 (8.7%) | 1239 |

Source: Altman (1993 p. 317).

Pimentel (1993) calculated a comparison of annual loss in dollar amounts for the U.S.A on the following periods which testifies that there was no major differences of losses inspite of sharp declines of pesticide uses (Table V). Some authors view that this is mainly due to two reasons: 1) the same or more acres being treated, and 2) lower rates of application of pesticides. In this respect, Whitten's (1992) remark is also worth mentioning. "The NRC (Avon, 1989) in the USA reported that there was a 46 percent reduction in insecticide usage on field crops in the country between 1976 and 1982 following uptake of IPM on cotton, alfalfa, apples, and peanuts. What is largely lacking to bring this revolution to reality in a sensible time frame is a preparedness by the consumer to pay higher prices for commodities and food stuffs produced under such systems" (p. 29).

TABLE V

COMPARISON OF PEST LOSSES IN THE U.S.

| Period | Insects | Diseases | Weeds | Total |
|---|---|---|---|---|
| 1986 | 13.0 | 12.0 | 12.0 | 37.0 |
| 1974 | 13.0 | 12.0 | 8.0 | 33.0 |
| 1954-1960 | 12.9 | 12.2 | 8.5 | 33.6 |
| 1942-1951 | 7.1 | 10.5 | 13.8 | 31.4 |
| 1910-1935 | 10.5 | NA | NA | NA |
| 1904 | 9.8 | NA | NA | NA |

Source: Pimentel (1993) p.439
NA=Not Available

It may be noted that there seemed a wide variation of losses between the study of Pimentel (1993) and Chambers and Lichtenberg (1994). One possible reason could be the former used dollar values and the later used production. Moreover, it is not known whether Pimentel considered the inflation factor in his calculation.

In addition, many authors were of the opinion that it was difficult to calculate the value, loss or benefits, because of the many social considerations such as indirect costs, environmental hazards, cancer, ground water pollution, residue in foods, ecological damages, reduction of fish and human poisoning (Krummel and Hough, 1980; Pimentel, 1979). However, whatever may be the differences of estimates on losses due to pests, it is an established fact that control of pests can be better managed by reducing the amount of pesticides. As a unique case, the suggestion to New York State growers to stop their regular 7-15 weekly sprayings of parathion to control adult onion flies was an example (Finch, Eckenrode, and Cadoux, 1986). In this particular case, for effective control of flies, the chemical sprays had to contact the flies. But the growers applied sprays when flies were not active in the crop. When the flies became active in the evening, the parathion residue on the plant foliage became low due to high temperature. The application of parathion as such was groundless as observed by Finch, Eckenrod, and Cadoux (1986). Subsequently the withdrawal of pesticides not only saved farmers' crop protection cost but also helped protect the environment.

Finch (1987) in another study on horticultural crops mentioned that among many factors which contributed to the increased amount of pesticides, the raising of cosmetic standards was the most important one. According to him, "Probably the most important has been the raising of cosmetic standards to the level where the presence of feeding scarls, and not necessarily the actual insects, is often sufficient to have crops rejected by processors, and even by the fresh market in many instances." (p. 258)

He further remarked that many horticultural systems were based on the assumption that appropriate pesticides would always be available. As such, he found that some growers avoided crop rotation and relied heavily on monocultures to increase their production. The most damaging part was that such practices were followed without any consideration of their effects on insect population. He observed that these were rather done for the conveyance of harvesting, handling and storage, when he stated that:

> The belief is that, provided a suitable insecticide is applied at the appropriate time, phytophagous insects will be prevented from building up to "pest" status. In case they are not, however, many growers produce, either intentionally but more so usually inadvertently, more crop than the market will support so that, should a particular pest make a resurgence, there should still be sufficient suitable produce remaining to supply the market's needs (p. 258).

Further, Benbrook, (1991) noted that for many farmers, the transition to a more sustainable agricultural system might need some short term sacrifices in economic performances to prepare for the biological, ecosystem and physical resource. These transitions were necessary for long term development in economic as well as environmental performances. The National Research Council (1989) revealed that there was little research directed towards farming interactions which were necessary for alternative agriculture. However, some authors also expressed a sign of shadow towards the success of alternative agriculture. As for example, they viewed that practices which were required for the improvement of alternative (sustainable) agriculture were not economically viable and were not likely to take hold on the farm.

Whatever maybe the contentions for and against alternative agriculture, I would argue that at present many farmers, consumers, conservationists, and political leaders share a common interest in the sustainability of alternative agricultural production systems. This argument may gain support when we observe the development of IPM (which is a subset of alternative agriculture, as I view it) as an effective program to prevent or mitigate losses caused by pests through the use of cultural, chemical and various other methods of control (Cutler, 1978). National IPM coordination committee (1989) stated "that the promised bright future of the pesticide era was soon clouded as the problems of secondary pests, pesticide resistance, and environmental and health hazards were recognized" (p. Foreword). It would not be an exaggeration to state that the favorable climate towards IPM helped alternative agriculture emerge as a more scientific and practical approach to pest control. Remarks of Long (1989) Deputy Assistant Secretary for Science and Education USDA Science and Education, further strengthened this statement when he stated:

> Ag chemicals are getting as much public attention and concern these days as sex or cholesterol! One result of all this focus has been increased legislative and regulatory activity. Congress and the states are passing laws based on incomplete and sometimes inaccurate information on the true risks of chemicals. Pesticides are under heavy scrutiny. Registrations of old and new materials are already slow and costly--and it will get worse.
>
> There is no question but the 1990 Farm Bill will contain environmental provisions that will be more demanding than the 1985 bill by requiring the use of the best management practices for agriculture's productive resources or imposing restrictions or penalties. The trends in this direction will certainly diminish the arsenal of available pesticides and may limit farmers' choices to more costly, less effective materials that will affect profitability. Too often, we have seen regulatory agencies react to public pressure on chemicals by deciding if you can't control it, ban it.

> In addition, increased pesticide resistance is adding to the problem as some of the most effective and safest pesticides have become, or are becoming, ineffective because pests and weeds are rapidly developing resistance to them. This trend is also true of newer biocontrols. If present regulatory and evolutionary processes continue, we may have few, if any, pesticides available to farmers by the year 2000--a mere eleven years away. Furthermore, not only is the American public confused and concerned, so are our American farmers. They don't want to be branded as the bad guys who are despoiling our natural resources. They have a healthy respect for the earth, and, after all, most farmers live where they farm.
>
> Hopefully, there will be other systems available to producers in future years. IPM is an important adaptation as a safer, more effective way to protect crops. It is a part of a broader effort within agriculture to produce a quality product safely, efficiently, and profitably. It fits in with our departmental priorities of groundwater quality and soil erosion, food quality and safety, and now LISA (low-input sustainable agriculture) (p. 4).

## Utility Concept, Benefit -- Cost and Decision Criteria

The review of literature in the foregoing sections led us to a point where everyone involved should reconsider alternative pest control strategies in the future use of pesticides. Of course, that is a broad policy issue to be decided by the policy makers as well as the public. However, one point in question is that in an economy, or a market, the main two actors who operate in the system are the producers and the consumers. The marketing tools serving as agents of producers, distributors, processors or manufacturers may influence the decision making criteria of the end users of the products - the consumers. But the producers or others involved in the process of production, working within the framework of prescribed norms set by the government, have one principal motive, profit maximization. In this context, Norgaard (1976) noted "the pest management goals of farmers are largely economic" (p. 18).

Keeping the economic aspect in mind, producers also consider other social responsibilities such as social justice, well being of the society, environmental concerns, health hazards, pollution and so on. Consumers, on the other hand, want to maximize their utility (satisfaction) from a given set of choices of goods (Koutsoyiannis, 1979). When making a decision to buy a product a consumer is constrained by his/her budget line (income), besides other things. To be more specific, consumers do face prices and have income constraints.

Consumers Budget Line: Any student of a beginning economic course knows that a consumer's budget line EF as depicted in Figure 1 shows the combination of goods that can be purchased with a given money income and price of goods held constant. The line EF is a straight line and the slope is constant at all points along it.

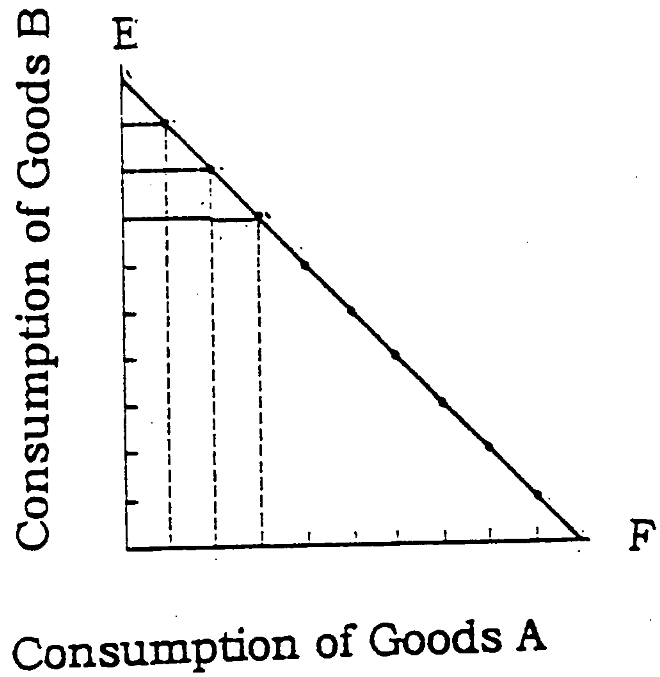


Figure 1. The Budget Line

In Figure 1, a consumer can purchase any basket (combination of goods) on or inside the budget line. This represents a mix of two goods or services that could be purchased by an individual who has a particular income and who faces a particular price for those goods and/or services. This reminds us of the idea of scarcity of a good due to limited income. Our consumers who are the end users of the products do not have unlimited money income. This point has been raised here with a specific purpose. Most of the time it is observed that many surveys are conducted to know the perceptions of the consumers such as whether they are willing to pay more money (increase of 5 percent, 10 percent, 15 percent, or 30 percent ) for goods free of pesticides (Baker and Crosbie, 1994). But while doing so, perhaps neither the researchers nor the respondents usually considered the limitation of budget lines faced by consumers.

The budget line represents a consumer's combinations or mixes of two goods A and B and/or services that could be purchased by him/her with a specific income. Note that consumer's choice is limited by income, and price is fixed (by assumption). We could incorporate this idea in the case of choosing between organic and inorganic products (just assume this for argument's sake because this is beyond the scope of this review to present all the details and limitations of this analysis ). Consumers will make a decision based on their perceptions of the value of utility of the product to them. But note that a utility which is a subjective measure of usefulness or satisfaction of wants simply occurs from consumption.

Now let us argue that price is not fixed. If the price of one good changes, but money income and the price of other goods does not change, the consumer's budget line also changes (rotates). If the price of good A falls but his/her money income remains unchanged, the budget line will rotate about point E, and will produce a new budget line EL as portrayed in Figure 2.

But note that the maximum level of consumption of good B possibly is unaffected, because income is still the same. If income increases and product prices remain unchanged, the budget line will shift to the right, which indicates the consumers can buy more of each product (1986; Browning and Browning 1992). To be more specific the slope of the budget line will not change, because prices remained unchanged. This is depicted in Figure 3.

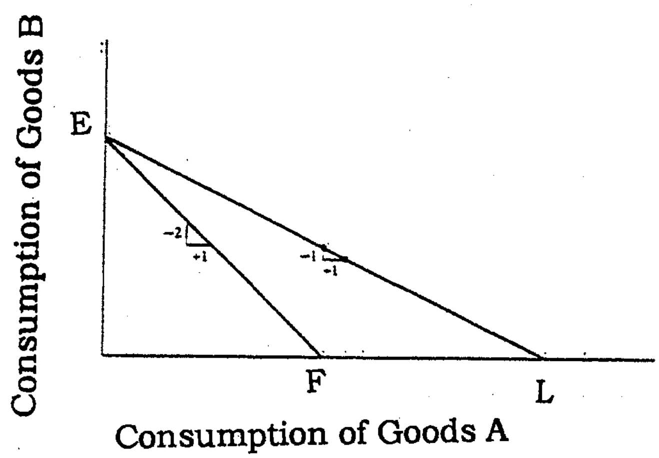


Figure 2. Consumption of Goods A

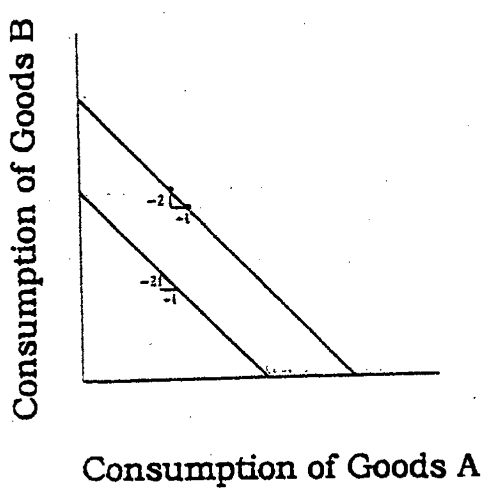


Figure 3. Effects of an Increase in Income on the Budget Line

The Consumer's Indifference Curve Utility and Decision Making Process: Budget lines identify the various alternatives available to the consumers. The shape and positions of the budget line will affect consumption decisions. But the specific mix of goods (what one wants) depends on the consumer's choice of alternative goods influenced by his/her subjective views based upon the aspirations or desirability/utility of the goods. Therefore, it is deduced or assumed that underlying tastes, preferences and/or subjective assumptions of the consumer plays a major influence/role on the decision making process. This decision making is reflected by the consumer's indifference curve where he/she ranks the market basket as equally satisfying. Of course this is based on some assumptions such as preferences and budget lines which influence choice, preference is transitive (consistent), and that more will be preferred to less. Based on these assumptions, a consumer's indifference curve such as U1, U2, as depicted in Figure 4 and Figure 5 indicate all the combinations of good H and good G for two different individuals, Rickey and Collins.

It may be noted that whereas utility analysis assumes that satisfaction can be measured, indifference analysis assumes that satisfaction can be ranked with different combinations of goods. This is important in our context because consumers can rank their preferences for goods with pesticides or without pesticides. These indifference curves are convex to the origin indicating that as one moves down, the slope of the curve becomes smaller which implies a diminishing marginal rate of substitution (MRS). A consumer's MRS is the maximum amount of one good that a consumer is willing to trade (give up) of one good for another unit of good. There are many shapes of indifference curves, which are not discussed here in this review. It is assumed that the consumer will or can purchase goods from among the available baskets (constrained by his/her budget line) which gives him/her the greatest satisfaction.

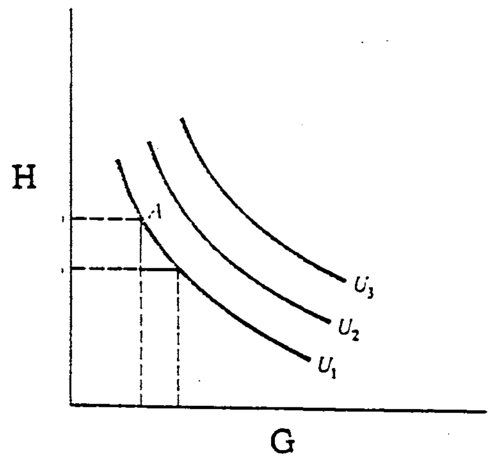


Figure 4. Indifference Map of Rickey

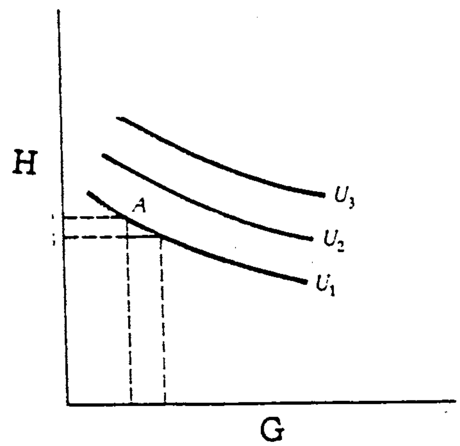


Figure 5. Indifference Map of Collins

From the above, it is assumed that the consumer derives satisfaction from the goods viewed from preferences which can be measured in terms of utility. Utility, as pointed out before, is simply a subjective measure of the importance and usefulness of the good (Koutsoyiannis, 1979). As such, it will be assumed that when a consumer opts for a good, say, which is free from pesticides or has fewer pesticide applications, or is pure organic, one acts according to his/her utility concept. A utility maximizing market basket of goods occurs where the consumer distributes his/her money income such that the marginal utility (marginal utility is the addition to total utility that is derived from the acquisition of one additional unit of commodity) divided by the good's price is equal for every good purchased.

The above brief theoretical background of utility explains to some extent why producers should produce goods, as for example, in our present case, products with less exposure to pesticides to meet the tastes, preferences and satisfaction (utility) and demand of the consumers.

Production Function: Producers producing goods will be guided by the production function which is a relationship between input and output. The production function identifies the maximum quantity of a commodity which can be produced in a given time period by combining specific inputs. The theory of productions functions will not be discussed in depth here. But it will be argued that a producer will take advantage of the available technology. In his/her decision making criteria to produce goods and to satisfy the market demand as such, he/she will be influenced by risks criteria under uncertainty. One point to be noted is that while demand theory of the consumer assumes that a consumer wants to maximize utility, a theoretical supply curve for the producers assumes that producers seek to maximize net returns (profits). This is done by equating marginal costs and marginal revenue. Since it may be assumed that a individual farm is a price taker, each firm's marginal revenue is the prevailing market price (Tomek and Robinson, 1990).

Usually in theoretical models of supply functions in agriculture it is assumed that prices are known (certain) and producers have control over output. On that basis planning decisions are made. But in actuality, those assumptions may not be correct. Because there is a time lag between planting and breeding decisions and the yield received, so this situation may result to two consequences. Price may differ from the time of sale from what was expected at the time of decision making to produce. This is known as a measure of price risk. Actual production may not equal planned production because crop yields may differ from those anticipated due to losses to pests, or adopting a suitable technology to manage pests, and/or unfavorable weather. This difference between actual and expected yield is a measure of yield risk. Therefore, yield and price risks may shift the supply schedule of the producers. A theoretical supply curve assumes that risks are constant although this is not so in practice. So, uncertainty about prices and yields must be considered to make production decisions. That is why the objective of the farm may not be profit maximization. Rather farms' objective is maximization of expected utility, which is a function of expected profitability of the producers and one's aversion to risk (Tomek and Robinson, 1990).

Comments on the Use of Pesticides: Before discussing risks, one additional issue needs to be presented here. It may be argued that much has been said about the adverse effects of pesticides to our present and future society. But in terms of this issue there is one unanswered question in the non-point source of pollution such as in agriculture. Who will bear the cost of such pollution? With regard to non-point source of pollution, the National Research Council (1989, p. 89) pointed out that:

> Agriculture is the largest single non-point source of water pollutants, including sediments, salts, fertilizers, pesticides and manures. Non-point pollutants account for an estimated 50 percent of all surface water pollution (Chesters and Schierow, 1985; Myers et al. 1985.)

Statement of National Research Council (1989) revealed how agriculture caused serious environmental problems. The Council further stated:

> Agriculture leaders and policy makers are currently confronting questions about contemporary production practices. It is important to note that many problems are prevalent only in certain regions and under specific management practices. Almost all of these problems can be overcome. Nonetheless, problems such as ground water contamination will likely grow if current practices are continued.
>
> Many of those problems have developed in large part as a result of public policies and thus may be overcome through policy reform. The important link among all these problems is that productive and profitable alternative practices are available in most cases and are already implemented in some (p. 90).

If the National Research Council's observations are correct on the availability of profitable alternative practices, then the barrier of implementation of such practices seems to be the lack of diffusion and adoption and/or influence of risk under uncertainty.

Risk Attitudes of Producers and Adoption of Technology: The question of adoption goes back to the attitude and perceptions of the farmer which comes from his/her benefit-cost ideas coupled with risks associated with such practices. The issue of risk to implement a production method or undertake a business strategy should not be confused with the risk of health and other environmental hazards associated with the use of pesticides. The producer's attitude towards risk is a decision criteria. For example "the alternative practices that they will follow might not be ones that will optimize production under all conditions but the farmer cannot afford to take risks using alternative practices that may occasionally fail completely, or cause yields to fall below the minimum he needs to survive. Thus, farmers' attitudes toward risk taking will also greatly influence their use of control methods" (Dent, 1991, p. 8).

All these issues influence a farmer's decision making process. However, regarding the benefit-cost concept, Strickland (1970) argued that the concept of benefit-cost in pest control was previously limited to explain the cost of a chemical regarding improvement in crop yield or quality. He mentioned that Ordish and Pimentel used this concept in developing and using resistant crop varieties. The author further added that Headley and Lewis put much emphasis on the social benefits and cash returns from pest control. They indicated the need to incorporate long run risks to man and wildlife from pesticides (which is different from risk attitude to a decision criteria). However, it may be contended that apart from all these risks associated with the use of pesticides, a risk attitude (under uncertainty) anticipated by the farmer regarding a decision criteria to follow a particular production method over other methods will affect and influence the implementation of benefit-cost strategies in the production process of the farmer.

Farmers are mostly business men (Strickland, 1970). If Wright (1910) is still correct today, "Every other consideration must be subordinated in favor of the cultivation of crops that will bring in the largest profit", then it is true that farmers will take steps or listen to the suggestions for alternative practices, if it is beneficial to them in terms of economic benefit (Strickland, 1970). If the farmer is satisfied with his/her earlier method, he/she will continue with his/her previous strategy and so it is unlikely that he/she will be receptive to changes (Norton, 1982). But if he/she is not satisfied, he/she is likely to look for a change. This is, I believe, what is happening in the use of pesticides.

Coming to the question of social benefits from the use of pesticides it is difficult to measure, because many issues are involved, especially who is getting the benefit and who is paying for it. Moreover, social costs are difficult to measure. These questions may also arise from any possible adverse effects of pesticides or for that matter any benefits as well. The other issue is that there are different views on the concepts of pest management principles and its effects held by farmers, society and personnel associated with agriculture and public health (Luckmann and Metcalf, 1982). Newsom (1979) noted:

> Accurate assessment of the contributions of a specific component of agricultural technology to increased crop yields and improved efficiency of labor is most difficult, if not impossible. The interactions between the various factors that affect production are too complex for the effects on yield of a single factor to be isolated (p. 153).

The National Academy of Sciences (1980) mentioned that pesticides are an essential ingredient of forestry and agriculture. It indicated that currently the benefits of pesticide use in agriculture followed a procedure known as "partial farm budgeting." They analyzed the benefits offered by pesticides in increasing crop yields. This procedure amounts to estimating the effects of alternative regulations of the use of a pesticide on the net farm income of growers of the crop where pesticide is used to protect the crop. "It therefore implicitly defines the economic effect of regulating a pesticide to be its effects on net farm income" (National Academy of Sciences, 1980, p. 9).

Productivity and cost effectiveness of pesticide is done by assigning monetary values to the real benefits that would be foregone if the pesticides were withdrawn or otherwise restricted. However, considering the risk under uncertainty, the National Academy of Sciences (1980) clearly indicated the economic effects of regulating pesticides was the difficulty of foreseeing how farmers will respond to regulations, in particular deciding what alternative methods of pest control they will employ.

I would, however, only attempt to present here a theoretical discussion on the decision making under uncertainty criteria based on producers' viewpoints arising from the expected utility model. An expected utility model is a single valued index which orders action choices according to the preferences or attitudes of the decision. Earlier, it was pointed out that one of the main goals of a business such as farming is to maximize profit. The returns to the individual farmer from pest management are the increase in the money value of the yield at harvest resulting from a particular pest management strategy. It may be noted that a farmer is also influenced by past performances and future expectations in his/her decision criteria.

If a farmer considers the production of crops, based on an expected utility model, then his/her risks under uncertainty will depend on the maximization of expected utility (Robinson, Barry, Klibenstein, and Patrick, 1984).

The expected utility model's objective function is: (1) Max EU(x) = EU(xij.) P(si). Let us assume that on the use of pesticides or not using pesticides, a farmer faces a risky alternative of having a maximum possible loss of $2000 with probability 1-P. The value of a farmer's utility function is fixed by assigning arbitrarily a utility value of 1 for the gain, U (2000) = 1.0 and a utility value of 0.0 for the loss, U (-2000) = 0.0 Values of utility for a farmer in monetary terms are found from the indications of certainty equivalents for alternative likelihood's of his/her gain or loss. However, it should be noted that expected utility theory (EU) seeks to express attitudes under risk conditions. Though prescriptive in nature, the EU is a unique method to depict the goals of a decision (Robinson, Barry, and Kliebenstein, 1984). The EU is based on some axioms about the individual behavior. The expected utility theory states that if the axioms hold, then optimal risky choice is dependent on maximization of expected utility. The set of axioms are as follows.

1) Ordering of choices: Preferences among alternatives can be represented by an ordering: faced with risky prospects, A1 and A2, decision maker (DM) prefers A1 to A2, A2 to A1 or is indifferent between them. 2) Transivity among choices: if A1 > A2 and A2 > A3 then A1 > A3. 3) Independence Axioms (substitution among choices): If A1 > A2, and A3 is some other choice, then a risky choice consisting of PA1 to (1-P) A3 > another risky choice say PA2 + (1-P) A3, where P is the probability of occurrence. 4) Certainty Equivalents among choices: If A1 > A2 and A2 > A3, then some probability P exists which will make the decision maker indifferent between having A2 for certain and a gamble consisting of PA1 + (1-P) A3. So A2 is the certainty equivalent of the gamble P(A1) + (1-P) A3. It is to be pointed out that in this process of decision making, four things are needed: values of A1, A2, A3, and P (where P is a probability assigned). If three of these items are pre specified, the decision maker presents a reasonable value for the fourth item. This methodology considers A1, A3, and P as the pre-specified values. It further assumes that the utility of the event certainty equivalent equals the expected utility of the risky alternative.

Therefore, any certainty equivalent is equal to probability. Mathematically $U(Z) = P(1.0) + (1-P) . 0 = P$, where Z = certainty equivalent.

However, coming to the risk attitude, it may be defined as a variability of income or net return which can be measured by variance, coefficient of variation et cetera. To make the discussion short, there are three kinds of decision makers: risk neutral, risk averter, and risk taker. A decision maker's (DM) preference toward risk is known from the utility function. A DM's risk attitude may be known from the shape of his/her utility function.

For the risk neutral, the utility function will be linear when he/she encounters an action with mutually exclusive monetary income (Figure 6). In Figure 6, the utility function is U(Z) = kZ for K>0. For risk averter, he/she faces a concave utility function (Figure 7). Risk averters will prefer a choice with a perfectly certain return to another action with an equal amount which is uncertain expected return. Here his/her utility increases as his/her wealth increases, because he/she has positive utility for money (first order condition > 0). But as his/her wealth goes on increasing, he/she will face diminishing marginal utility (second order condition = 0). For the risk lovers, the utility curve will be convex (Figure 8). Figure 6 depicts position of risk neutral utility function. A decision maker may also have utility functions U(Z) with concave and convex segments which indicates changes in risk attitudes for various monetary outcomes.

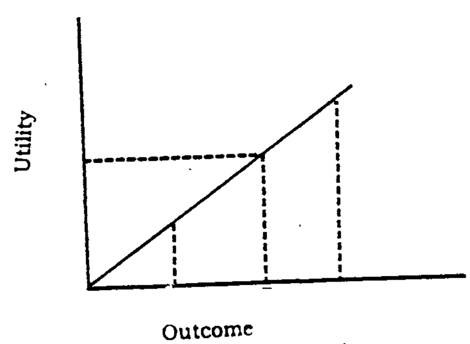


Figure 6. Risk Neutral (constant) Utility Function.

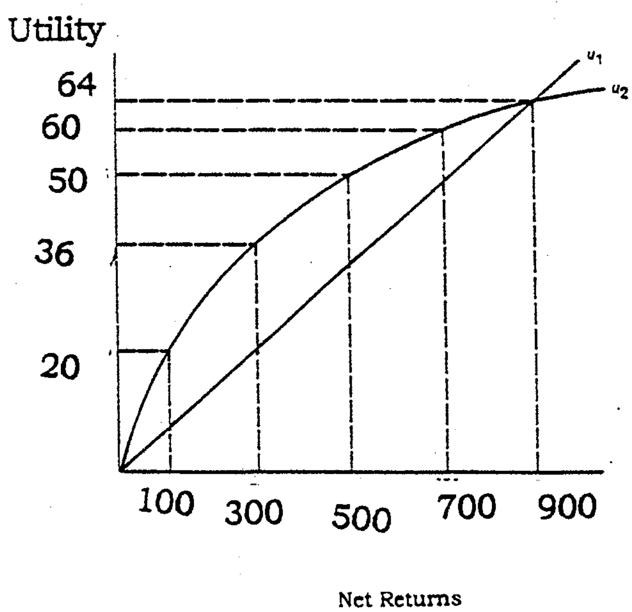


Figure 7. Risk Neutral Utility Function of a Risk Averter (Concave Function)

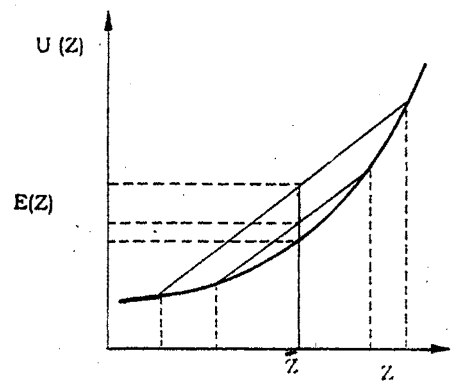


Figure 8. The Utility Function of a Risk Lover Producer (Convex Function)

It is normally assumed that a decision maker has rational expectations. However, the main problem facing a producer/or decision maker (DM) is to form a choice among alternative probability distributions associated with each management system (in our case, pest control devices). Figure 7, (based on the work of Von Neuman and Morgenstern ,1947), shows the utility function of a DM to rank all the possible outcomes. The value of each outcome is referred here as utility. It may be pointed out that quoting, Arrow (1974) Robinson et al (1984) noted:

" (a) Individuals tend to display aversion to the taking of risks and (b) risk aversion in turn is an explanation for many observed phenomena in the economic world." (p. 3).

As portrayed in Figure 7, there are two representative utility functions. (1) Risk neutral represented by U1 and risk averter, represented by U2. U1, which represents a risk neutral DM's utility for each outcome, is the dollar value of that outcome. The risk neutral D.M.'s utility function is a straight line (also shown in Figure 6) which means that a gain or loss of income is considered having the same value to the DM at any level (Antle, 1988).

According to Von Neuman and Morgenstern (1947), under uncertainty, a rational DM makes choices based on his/her utility which relates to each outcome and the related probability associated with it. In Figure 7, it has been shown that a risk averter DM utility function is concave and he/she considers values of increments to an outcome as an increase at a decreasing rate i.e. marginal utility - decreases. To give a specific example of pest management action a subjective probability distribution are given in Table VI among three different choices with five intervals.

TABLE VI

PROBABILITY DISTRIBUTION AMONG DIFFERENT ALTERNATIVE ACTIONS

| Alternative Actions | Probabilities of Net Returns (outcomes) | | | | |
|---|---|---|---|---|---|
| | 0-200 | 200-400 | 400-600 | 600-800 | 800-1000 |
| Follow Scouting to control pests | .10 | .20 | .50 | .15 | .05 |
| Follow usual pest control | .10 | .25 | .40 | .20 | .05 |
| Do not spray | .17 | .38 | .25 | .16 | .04 |

With utility function $U_2$ in Figure 7, the expected utility of different alternatives are as follows: 1) follow scouting 46.4; follow usual pest control 46.2 and do not spray 41.74. From this analysis, it appears that a risk averter DM will select scouting as a pest control method. It needs to be pointed out that the utility are arbitrary and they do not correspond to monetary values (Antle, 1988).

The above discussion explains that in the decision making process of a person, uncertainty plays an important role. So while making any decisions, for an alternative agricultural practice, a farmer will be influenced by the risks associated with it. "Risks face us with the possibility that something untoward may occur, while leaving us unable to foretell any specific outcome with categorical assurance" (Rescher, 1983, p. 5).

So the risk neutral DM makes a decision having the greatest expected utility which equals the outcome with the greatest average value. A risk aversion DM, (U2 in Figure 8) considers increments to an outcome at a decreasing rate. The decreasing slope of the curve indicates risk aversion. The concave utility function represents that the value of an additional dollar of return has less worth at higher income levels than at lower income levels. The risk averter is willing to trade off some income (say to use pesticides and also buy insurance) to protect against the chance of great loss (Antle, 1988). "It seems to be a widely held view that a substantial portion of the total pesticide applications occurs for insurance purposes and that perceived risk and risk aversity are the major determinants of whether or not farmers adopt new pest management" (Norgaard, 1976, p. 23).

Further It may be noted that the avoidance of risk is a criteria that must be considered against profit maximization over the long run (Norgaard, 1976). Norgaard further noted that the views of the farmers in using more pesticides as an insurance against pest damage "leads to proposing pest damage insurance schemes as a substitute for pesticides to reduce use and to speed the adoption of new techniques" (p. 23).

The farmers may not know the sophisticated mathematical tools to measure risk, but they are smart enough to make subjective judgments with their decisions. Normally, most farmers are risk averters. In this context Handerson and Quandt (1980) contended that "Introspection and observed behavior suggest that most people are risk averse in most of their dealings" (p. 57). However, my idea on risk aversion is based on the philosophy of extension. When a new technology (say about pest control) is introduced farmers initially may not like to take the risk to adopt new ideas. But they may rely on the efficient flow of information in pest control decisions. This information coming from various extension services may gradually reduce uncertainty in pest control decisions (Lawson, 1982).

Concluding the risks analysis associated with pesticides for environmental damage (this risk is different from risk under uncertainty to undertake a business venture), it is noticed that risk assessments are usually triggered by scientific information indicating detrimental effects on human health and on the environment (Krummel and Hough, 1980). However, it is difficult to put a value on the risk assessment. As Antle (1988) noted:

> It is especially difficult to determine the external costs of pesticides - their effects on pest resistance, the environment and human health. Some of these effects can in principle be quantified; others involve valuation of non-market goods; still others, such as the valuation of human life, are highly controversial. The scientific foundations and data for quantifying the external effects of pesticides range from very solid to quite shaky. In the case of pest resistance to certain chemicals, there is sound scientific understanding and sample data. Also, effects of certain pesticides on human health are well-known. But in many cases the basic science is not well understood, nor is the epidemiological evidence adequate for drawing reliable inferences about health effects (p. 3).

Moreover, for many problems relating to the environment, it is not possible to emphasize with certainty the consequences of a particular policy. This is because scientific estimates themselves are often imprecise (Antle, 1988). The above discussions put forward by Krummel and Hough (1980), and Antle (1988) are, however, related to general risks association with pesticides. These risks also play an important role in making decisions which of course vary from individual to individual.

On the basis of the above discussion, it is argued that if farmers are risk averters, then a ban on the use of pesticides may induce a farmer to suffer from economic loss because he/she may not be sure about the efficiency of alternative control methods (Metcalfe, 1982).

I would emphasize that at present (as before) there is a great need to make the fruits of effective research available to the farmers via extensive extension information. Unless this can be achieved, it will be difficult to implement the policy of alternative agriculture or for that matter any other method of farm management to the farmers. Because of uncertainty, a producer may tend to be a risk averter and a possible step to change that position is to create awareness through demonstrations. As Rescher. (1983) noted:

> The cure for uncertainty is fuller information - and this may simply not be available in the present state of the art. If it is to become available, the search - or rather research - that yields it will generally require time and resources, and the opportunity costs of attaining the security it affords can be very high, perhaps too high to be affordable. And the fact remains that we must generally act here and now; a choice put off until "all returns are in" is generally a choice that will never be made at all. Here as elsewhere, cost-benefit considerations come to the fore (p. 141).

In summary, the researcher would contend that agricultural policy analysis such as withdrawal of pesticides needs to be studied further. In many cases, agricultural policy models and analysis have mostly ignored many risk considerations (Gardner, Just, Kramer, and Pope, 1984). In this context they stated:

> One can only conclude that either the researcher does not believe that risk response is important, or that difficult, unresolved questions still exist about the appropriate method of analysis. Probably both reasons govern research behavior, but we believe that the empirical applications of existing methods and the development of new methods warrant attention. Acceptance of risk averse expected utility behavior has substantive implications for welfare measurement and conception and, indeed, may be the raison d' etre for much agricultural policy. This should be impetus for further risk research (p. 261).

## Summary

The ever increased growth rate of the population created a worldwide pressure to increase agricultural productivity, efficiency and profitability. But pests also competed with man for their food and along the way farmers from time immemorial used a variety of methods to control pests. However, the discovery of synthetic pesticides after World War II increasingly encouraged developed countries to depend mainly on chemical control as a single measure of pest management. No doubt the development of modern pesticides helped increase agricultural productivity. But it brought many deep rooted problems for human beings, the environment, and the ecological conditions. These problems or adverse effects led to a growing public awareness and concern about the widespread use or misuse of pesticides on public health and on ecological conditions. Consequently, various efforts for judicious pest management re-emerged which may be called alternative control methods in agriculture. These methods put emphasis on cultural practices, and use of multiple control methods with less dependence on pesticides. But it is not clear at this time whether these methods would ultimately tend to eliminate the use of pesticides. Certainly these alternative control methods aim to reduce dependence on pesticides. IPM, as an alternative control measure, is one of such approaches.

In general, pest management policy goals or decisions of producers to adopt any alternative measure are mainly economic. But while making decisions under uncertainty, the benefit-cost concept and risk attitudes of farmers play a major role. From the behaviors of decision makers, it is observed that most people are risk averters.

# CHAPTER III

# METHODOLOGY

## Introduction

The purpose of this chapter was to describe the procedures followed and methods used to conduct the study. A population was determined and an instrument developed to collect data satisfying the objectives of the study. The development of the instrument was coordinated by a team. Details are described below under the headings of survey area and survey team.

A complete review of previous studies was used to design the survey instruments to meet the objectives of the study. Survey reports of Baker, Smith, O'Day and Jarman (1992); Waldrum (1982); Hamilton and Meyer (1992); Ferguson and McCalla (1981); Johnson (1991) and Spradley (1991) were evaluated regarding methods of data collection and patterns of questions.

## Institutional Review Board (IRB) Statement

According to both Federal regulations and Oklahoma State University policy, it is required to review and approve all research studies that involve human subjects before any investigator can begin his/her research. To protect the rights and welfare of human subjects involved in biomedical and behavioral research, the Oklahoma State University Office of University Research Services and IRB conduct this review. In compliance with the aforementioned policy, this study project received the surveillance of IRB and permission to continue the study was granted via memo IRB#: AG-95-004. Refer to Appendix C for IRB approval.

## Objectives of the Study

The objectives of this study were to:

1) determine number of acres of greens, spinach and varieties of crops planted, harvested, and average yield per acre obtained;

2) determine acres of land treated with pesticides and types of pesticides used (insecticides, herbicides and fungicides);

3) determine methods of application of pesticides;

4) identify pests which caused the greatest money loss;

5) determine the trends of pesticide usage during 1990-1994;

6) determine alternative control methods used (including cultural practices to control pests (insects, diseases and weeds);

7) determine methods of monitoring fields against pest (scouting);

8) determine views on Integrated Pest Management (IPM); and

9) determine what the food processors would like the Oklahoma Agricultural Cooperative Extension Service (County Extension Agents) and IPM Area Specialists to accomplish to help improve their business.

## Procedures

The population of this study consisted of all the four food processors who process greens (collards, kale, mustard, turnip greens) and spinach in Northeastern Oklahoma. The processors buy more than 95 percent of greens and spinach produced by the farmers (Motes,1994 and Damicone, 1994). They determine the quality and standards to be maintained by the producers. Processors also have better technical expertise for pest control methods (Motes, 1994). Therefore, processors were selected as the population for the survey.

The survey was designed to collect information on planting and harvesting of greens, uses of pesticides, and alternative control methods practiced. All four food processors in the population responded to the survey. There were 27 green and spinach producers who had grown these crops under contract for the food processors. A survey of pesticide use on processing greens (collards, kale, mustard, turnip greens, and spinach) was conducted in Spring, 1994 in Northeastern Oklahoma. The producers who grew these crops for the processors were from the counties of Adair, Cherokee, Haskell, Leflore, Muskogee, Sequoyah, Tulsa, and Wagoner in Northeastern Oklahoma and Caddo county in Southwestern Oklahoma. Due to soil type, climatic conditions, and availability of water supply in these areas, - the Arkansas River Valley turned out to become a major vegetable producing belt in Oklahoma (Brewer, 1956). Brewer (1956) also mentioned that in the Fort Smith, Arkansas area the main vegetable crops were spinach, turnip greens, mustard and kale. Similar views about the importance of greens, especially spinach, in Oklahoma were also expressed by Wiggans, Marshall, and Odell (1963). As such, this area was selected for the study.

Moreover, Brewer (1956) mentioned that 73 percent of the growers/producers of greens marketed their products through processors. It was mentioned before that Motes (1994) and Damicone (1994) revealed that more than 95 percent of greens and spinach are marketed through the food processors. Therefore this survey was targeted at the food processors. In addition, the norms (rules, regulations, practices, quality, etc.) for the production of greens and spinach determined by the food processors or buyers had to be followed by the producers (Motes, 1994). So it is imperative to know the views or opinions of the food processors involved in the production of greens and spinach.

## Development of the Survey Instruments

A three member survey team was formed to develop the questionnaires. While developing the questionnaires, expert opinions were also utilized. These opinions came from professionals in the Plant Pathology, Horticulture, Entomology, and Agricultural Education departments. The team met periodically over a period of five months to develop a detailed survey form. This process served as a measure of validity.

The questions were divided into two sets. Set 1 contained information on production, varieties, yield, pests controlled and pesticides used (Appendix A).

In Set 2, (Appendix B) all the questions were directed towards the current practices of alternative methods, cultural practices (scouting, row spacing, crop rotations), awareness and perceptions on alternative agriculture, major pest problems associated with greens and spinach production, trends on the use of pesticides during the last five years, and views on IPM, as well as future use of pesticides on the greens and spinach.

The questionnaires were mainly direct response items where potential participants provided specific answers, selected one response from multiple categories (question on IPM) and/or rank ordered a list of possible responses. The questionnaires also contained some open ended questions to which respondents could provide their opinions. As mentioned before, validity of these surveys was done by obtaining opinions suggested from the experts in the field. Since the population was small, no reliability test was done.

The first item in the first questionnaire ( set one ) was formulated to collect data on acres and varieties on planted harvest and yields. This item met the ideas of objective number one.

The second through fourth items in the first questionnaire was designed to gather information about pesticides used to control pests (insects, diseases and weeds), percent of control, number of applications, methods of application of pesticides and names of applicators ( applied by whom ). These items addressed second and third objectives.

Item number four in the set two aimed to get the processors' observation on the pests (insect, weeds and diseases) which caused the greatest money loss for the crop they grew. This item addressed objective number four.

Item number thirteen was designed to gather information on the trends of usages of pesticides during the five years 1989-1994. This item addressed objective number five.

Item number one to three in the second questionnaire (set two) solicited information on the alternative control methods used such as crop rotation, resistant varieties and seeding rates. Item 9 was meant to identify processors' awareness about test for soil fertility. Item number 10 asked the processors to identify how they rotated their greens and spinach. All these items addressed objective number six.

The fifth through eighth items asked the processors about their current pest monitoring systems. These items addressed objective number seven.

Item eleven used a Likert-type scale to solicit the processors' response to the question of the cost effectiveness of IPM. Item number twelve was an open ended question designed to solicit qualitative views of the food processors on IPM. These items addressed objective number eight portraying a picture of attitudes on alternative agriculture in general and IPM in particular.

Fourteenth and fifteenth items also used open ended questions to solicit the processors' valuable suggestions in the areas they would like Oklahoma Cooperative Extension Agents (County) and IPM Area Specialist to accomplish to help food processors improve their business and also their views on the future use of pesticides in the greens and spinach respectively. These items addressed objective number nine.

## Collection of Data

A personal interview through printed questionnaires was considered to be the most efficient method of obtaining information/opinions from the food processors of the greens and spinach.

Though the entire population of greens and spinach producers was covered, the number was only four. As such, no data base was designed. As mentioned there were, however, twenty seven growers who grew these crops under written contracts with the processors. There were five kinds of crops: collards, kale, mustard, spinach and turnip greens. Out of the four food processors, only one processed all the crops, two processed only spinach and the remaining one processed collards, mustard and turnip greens only. Production data such as number of acres planted, varieties grown and pesticides used, et cetera. for growers of one processor processing spinach (i.e., responses to questionnaire set 1) were not available for the Spring of 1994 because one of the three processors who processed spinach did so outside the study area (geographic). For the same processor, relevant data during the Fall of 1993 was also incomplete. Since that processor processed spinach in the study area in the preceding seasons answers on questions numbered 4 to 15 ( questionnaire set 2 ) were solicited. This was done because these questions pertained to cultural and alternative practices, and not to any specific season. In addition, these questions also sought opinions and suggestions from the processors on the usage of pesticides.

Usages of pesticides by the growers for the processor who did not process spinach in the Spring of 1994 was not accounted for in this study. But views expressed on the alternative practices, specially IPM, and trends of pesticides usage during the last five years (other than Spring 1994) were included. It has been mentioned in this chapter and also elsewhere that the food processors in Northeastern Oklahoma grew greens and spinach and used pesticides to produce these crops. It should be noted that the processors did not grow these crops themselves in the survey area. They had those crops grown for them (under contract )by the producers. This point should be kept in mind while reading this report.

## Survey Methodology

During the Spring 1994 and Fall 1993 survey of the food processors on greens and spinach the following basic information was requested on the survey.

1. County Name (optional)
2. Crops
3. Season (Spring and Fall)
4. Varieties planted
5. Acres planted
6. Acres harvested
7. Average yield per harvested acre
8. Pesticide trade names (insecticides, fungicides and herbicides)
9. Number of applications
10. Crops and acres treated
11. Pest treated
12. Percent of control
13. Methods of application (ground, air)
14. Applied by (self, commercial)
15. Alternative control methods used in place of pesticides (insecticides, fungicides and herbicides).
16. Number of times alternative control methods applied
17. Percent change of alternative method in pest control

18. Percent change of alternative control method cost from normal production system

19. Types of insects, weeds and diseases which caused greatest money loss

20. Most common methods used to determine pest control scheduling

21. How scouting is done

22. Time required to scout a 10 acre field

23. Soil fertility test

24. Crop rotation procedures for greens and spinach

25. Views on Integrated Pest Management

26. Trends (estimate) on the use of pesticides during the last 5 years

27 Suggestions on the future usage of pesticides

28. Opinions (i.e. future help) as to what they would like the Oklahoma Cooperative Extension Service (County Extension Agents) and IPM Area Specialists to accomplish in the next 2 years.

An initial contact was made with the food processors during the Ozark Food Processor's Conference in Springdale, Arkansas on April 6 - 7, 1994. Sample questionnaires were distributed to the food processors on that date and a background on the survey was explained to them in the meeting. They indicated that they had the information needed which would negate the need to survey the producers. Later, telephone contacts were made with the food processors and dates were scheduled to visit them at their convenience. On the scheduled dates, questionnaires were again distributed. Out of the four food processors, two processors answered the questionnaires through interview method only. Some of the answers to the questionnaires were incomplete in nature. One processor answered part of the questionnaires through interview and the rest was returned later by mail. This processor also answered some questions when contacted by telephone. The other processor filled out the survey forms and on the scheduled meeting date, the survey team met with the processor to finalize the survey. This particular processor also shared views on many occasions when approached by telephone. Data collection began in May 1994 and continued through August 1994. In summary, all the food processors were cooperative. They extended their help and expressed their concerns on policy issues and implications of the future pesticide use and pest control methods for processing greens and spinach.

## Analysis of Data

Survey forms were coded to maintain confidentiality. As already mentioned, since the number of observations was small, no data base was designed and no statistical analysis to predict future usage of pesticides and norms was attempted. However, this analysis depicted a picture of the actual scenario at the farm level which was represented through descriptive statistics. This description revealed a comparative situation in different seasons for which data were available. Key (1993) pointed out that descriptive statistics also serve as a useful tool to present the findings of some research. The numbers presented through descriptive statistics provide some necessary information. As pointed out by Key (1993) "The primary use of descriptive statistics is to describe information or data through the use of numbers. The characteristics of groups of numbers representing information or data are called descriptive statistics" (p.175).

For the questions where participants were asked to give their opinions, such as advantages and disadvantages of IPM through open ended questions or to list the most damaging insects, findings were presented in the form of suggestions or opinions. For all other cases, tables were presented along with detailed description.

## Limitations of the Survey

The results of this pesticide use survey is limited to the answers/opinions provided by the food processors. As some of the answers were left blank and the size of the sample was low (although the whole population was covered), empirical pesticide use and pest control data should be interpreted with caution.

It is an established norm that the use of pesticides depends on the outbreak of insects, weeds and diseases. As was observed from the field survey, some of the growers did not have serious insects and disease problems in the Spring, 1994 produced crops. Spring greens are short period crops. If Southern peas were grown before greens, then some of the weed problems could be decreased. Similarly if greens were cut 3-4 times, many of the diseases could be controlled. These are some of the observations from the survey. These factors should be considered when interpreting the survey results. It is further viewed that if alternative practices ( cultural practices ) followed properly, then use of fungicides could possibly decrease to a large extent, if not stop totally.

# CHAPTER IV

# PRESENTATION AND ANALYSIS OF DATA

## Introduction

The purpose of this chapter was to analyze the usage of pesticides and alternative practices followed by the food processors for the production of greens (collards, kale, mustard, turnip greens) and spinach, which were grown for them under written contract by the farmers. Though this study is mainly related to the producton of greens and spinach, usage of pesticides, and alternative practices used during the Spring of 1994, an attempt was also made to provide similar figures for the Fall of 1993 and the overwinter of 1993 (for spinach only) wherever possible.

## Findings of the Study

The following section provides an analysis of the data collected in the study. There were five crops: collards, kale, mustard, spinach and turnip greens. Data for each crop was described separately. Since spinach is the most important vegetable grown among the five crops, data for this crop were described first. Thereafter, the data for other greens were analyzed in the alphabetical order of their names.

### Spinach

Spinach is mainly a cool season, long day and short night plant.

Production, Yield, and Varieties of Spinach Produced During Spring of 1994, and Fall and Overwinter of 1993. Production, Yield and Varieties of spinach during the Spring of 1994, Fall and Overwinter of 1993 are presented below.

Number of Processors: 2 processors (Spring); 1 Processor (Fall); 1 Processor (Overwinter)

Total acres contracted by these processors: 493 (Spring); 363 (Fall); 1150 (Overwinter)

Average number of spinach acres per processor: 247 (Spring); 363 (Fall); 1150 (Overwinter)

Average yield of spinach per acre: 2.33 tons (Spring); 3.2 tons (Fall); 4-5 tons (Overwinter)

Varieties included: Hipack, Avon, Coho and Chesapeake.

Detailed information on varieties grown, acres planted, acres harvested and average yield per harvested acre is presented in Table VII. It may be mentioned that for some acres of spinach separate varieties were not available. Therefore, total number of acres planted represented a combined figure for all those varieties.

TABLE VII

PRODUCTION, YIELD AND VARIETIES OF SPINACH

| Season | Varieties Planted | Acres Planted | Acres Harvested | Average Yield Per Harvested Acre |
|---|---|---|---|---|
| Spring 94 | Hi Pack | 33 | 33 | 5 tons |
| | Coho, Avon, Chesapeake | 460 | 375 | 2.1 tons |
| Fall 93 | Fall Green, AR-88-354 | 363 | 300 | 3.2 tons |
| Over Winter 93 | Avon, Chesapeake, 424 | 1150 | 1000 | 4 - 5 tons |

<u>Insect Control - Use of Insecticides:</u> One of the two food processors processing spinach did not use any insecticide in the Spring of 1994. The insecticide Permethrin was applied to 460 acres by the other processor in the season. As indicated in Table VIII, permethrin (Pounce) and *Bacillus thuringiensis* Berliner *Kurstaki* (Biobit) was applied by commercial aerial applicators. Two applications were made and insect control was considered by one processor to be 90 percent successful. During the Fall of 1993, permethrin and *Bacillus thuringiensis* var. *aizwai* were applied to 363 acres. Two to three applications were made and control was considered by one processor to be 80-90 percent effective. During the overwinter of 1993, permethrin and mevinphos were applied to 1100 acres of spinach. One to two applications were made and the control was considered by one processor to be 50 to 90 percent successful.

TABLE VIII

USE OF INSECTICIDES ON SPINACH

| Season | Insects Attempted to Control | Acres Planted | Acres Treat-ed | Pesticides Used | No. of Appli-cations | % of Control | Methods of Application | Applied by Whom |
|---|---|---|---|---|---|---|---|---|
| Spring 94 | Lep. Larvae | 493 | 460 | Permethrin | 2 | 90% | Aerial | Commercial |
| Fall 93 | Lep. Larvae Grass-Hoppers | 363 | 363 | *Bacillus thuringiesis Berliner Kurstaki,* Permethrin | 2-3 | 80-90% | Aerial | Commercial |
| Over Winter 93 | Lep. Larvae, Aphids | 1150 | 1100 | Permethrin Mevinphos | 1-2 | 50-90% | Aerial | Commercial |

<u>Alternative Control Methods</u>: Of the two, one processor did not report any use of insecticides. The one who used no insecticides also did not mention using any alternative methods

to insecticides. The processor who used insecticides reported having no alternative available in place of insecticides to control insects. The processors suggested that in the absence of insecticides it was necessary to grow resistant varieties. However, as reported by the processors, no resistant varieties to insects are available now and if resistant varieties of crops were developed, they must have potential to increase yield, otherwise the processors or producers would not use those varieties.

Disease Control - Use of Fungicides: Of the 2 processors for spinach, one did not use any fungicides to control diseases after planting. As mentioned before, there were about 493 acres of spinach contracted by the processors. However, the number of acres harvested by the processors in the survey areas were 408 acres. One processor reported using metalaxyl pre-plant to control soil-born diseases. Metalaxyl was applied in the fall and spinach was harvested in the spring.

Another processor applied metalaxyl to control white rust (*Albugo occidentalis*). The method of application was aerial and the control of disease was considered by one processor to be 85 percent successful. Metalaxyl was the only fungicide reported for control of the disease, white rust. During the fall and overwinter of 1993 the processors did not report use of any fungicide or outbreak of any disease. The use of fungicides is described in Table IX.

Alternative Methods used in Place of Fungicides to Control Diseases: Two respondents reported using resistant varieties of crops as an alternative to the use of fungicides. During Spring 1994, resistant varieties were used as an alternative to control diseases on 200 acres of spinach, whereas in 100 acres, crop rotation was used.

TABLE IX

USE OF FUNGICIDES ON SPINACH

| Season | Diseases Attempted to Control | Acres Treated | Fungicides Used) | No. of Applications | % of Control | Methods of Application | Applied By Whom |
|---|---|---|---|---|---|---|---|
| Spring 94 | Not reported | 33 | Metalaxyl (pre-plant) | 1 | 90 | Ground (pre plant) | Self |
| | White Rust | 200 | Metalaxyl | 2 | 85 | Aerial | Commercial |
| Fall 93 | None Reported | | | | | | |
| Over Winter | None Reported | | | | | | |

One processor contracting 33 acres of spinach mentioned crop rotation and resistant varieties as alternatives to fungicides. But that processor also indicated that due to shortage of land, crop rotation was not a feasible option. So it appeared that perhaps, in most cases, resistant varieties were used as alternatives control to diseases. This processor indicated that use of resistant varieties and crop rotation helped decrease white rust by 5 percent while for blue mold (downy mildew) it was not effective at all. But use of resistant variety and crop rotation increased costs by 100 percent.

Another processor indicated resistant varieties and crop rotation increased disease control by 10-25 percent and 15-30 percent respectively. However, this processor indicated that in the case of resistant varieties, cost increased by 10-15 percent; whereas crop rotation increased cost by 30-35 percent. Crop rotation as mentioned was not a viable option as an alternative control measure in view of the short harvest period. The processors indicated that this was applicable for all green crops and spinach. Data for alternative control methods in place of fungicides to control diseases during Spring 1994 and Fall 1993 are presented in Table X.

TABLE X

ALTERNATIVE CONTROL METHODS USED IN PLACE OF FUNGICIDES

| Season | Diseases Attempted to Control | Alternative Control Method Used | Acres Planted | Acres of Alternative Methods | No. of Times Alternative Control Methods Applied | % of Change in Disease Control | Changes in % of Cost from Normal Production System |
|---|---|---|---|---|---|---|---|
| Spring 94 | White Rust | Resistant varieties, | 33 | 33 | Not reported | White Rust decreasedby 5%, blue mold decreased by 0% | Increased by 100% |
| | Blue Mold | Crop rotation | | | | | |
| | White Rust | Resistant varieties | 460 | 200 | 1 | increased 10-25% | increased 10-15 |
| Fall 93 | White Rust | Delay in planting dates | 363 | 230 | 1 | increased 10-50 | increased 30-35 |
| Over-Winter 93 | White Rust | Resistant Varieties, Crop Rotation | 1150 | 250<br>200 | 1<br>1 | increased 20-60 | increased 20-40 increased 30-60 |

<u>Weed Control - Use of Herbicides</u>: Of the two processors growing spinach, one did not use any herbicide (Table XI) during the Spring of 1994. The total number of acres treated with herbicides was 150 acres. The most common weeds reported were Sibara (Sibara *Virginica L. Rollins*), May weed (*Anthemis cotula*) and Henbit (*Lamaium amplexicaule*). According to the respondents, phenmediphan was the only herbicide used in Northeastern Oklahoma to control weeds on spinach during Spring of 1994. This herbicide controlled about 80 percent of weeds (mainly Sibara and May weeds). All herbicides were applied with ground equipment by farmers. During the Fall of 1993 cycloate was applied to 250 acres to control grasses and broad leaf weeds. One application was made and the control was considered by a processor to be 70 percent successful. Similarly, to control broad leaf weeds and grasses, phenmediphan and cycloate were applied to 800 acres for overwintered spinach, and the control was considered to be 65 to 80 percent successful by one processor. Moreover, under section 18 crisis exemption, for the overwintered crop, 590 acres were treated with dual herbicides at planting to control Sibara. Dual

herbicides were used due to the loss of Antor. This processor reported that cycloate could not control all overwintered weeds in Spinach fields. Therefore, phenmediphan was used as a post-emergence weed treatment.

TABLE XI

USE OF HERBICIDES ON SPINACH

| Season | Weeds Attempted to Control | Acres Planted | Acres Treated | Herbicides-Used | No. of Applications | % of Control | Methods of Applications | Applied By Whom |
|---|---|---|---|---|---|---|---|---|
| Spring 1994 | Sibara, May weed | 493 | 150 | Phenmedi-phan | 1 | 80% | Ground | Self |
| | Henbit | | - | Did Not use any | - | - | - | - |
| Fall 1993 | Grasses, Broad Leaf | 363 | 250 | Cycloate | 1 | 70% | Ground | Self |
| Over Winter | Broad Leaf | 1150 | 800 | Phenmedi-phan Cycloate | 1 | 65 to-80% | Ground | Self |

<u>Alternative Control Methods used in Place of Herbicides to Control Weeds</u>: All respondents mentioned hand pulling and hand hoeing as an effective alternative to herbicides. The main weeds listed were Sibara and Henbit.

The processors used alternative control methods in 283 acres of spinach out of 493 acres. Hence the alternative control methods used in place of a herbicide stood at 57 percent. Successful control was reported by one processor to be within the range of 85 percent to 95 percent. On the average it was 90 percent successful. All processors mentioned pulling or hoeing as an expensive alternative control method. Moreover, one processor reported that sometimes it was difficult to get crews to do the job. Unemployment figures for these counties were: Adair 5.9, Caddo 8.3, Cherokee 7.8, Haskell 15.3, Leflore 9.8, Muskogee 8.6, Sequoyah 9.5, Tulsa 6.1 and Wagoner 7.5 (Department of Commerce, 1993). Data on alternative methods to control weeds in place of herbicides are presented in Table XII.

TABLE XII

ALTERNATIVE CONTROL METHODS USED IN PLACE OF HERBICIDES ON SPINACH

| Season | Weeds Attempted to Control | Acres Planted | Alternative Control Methods Used | Acres Treated | No. of Times Alternative Control Methods Applied | % of Change in Weed Control | Changes in % of Cost from Normal Production System |
|---|---|---|---|---|---|---|---|
| Spring 94 | Sibara | 460 | Hand Hoeing | 250 (average of 200-300) | 1-2 | 85 | 30-50 |
| | Henbit | 33 | Hand Pulling | 33 | 1 | 90 | 200 |
| Fall 93 | None Reported | 363 | | | | | |
| Over Winter | Shepherds Purse, Sibara | 1150 | Hand Pulling, Hand Hoeing | 300-400 | 1 | 85 | 30-50 |

## Collards

Collards belong to the cabbage family and is a non heading type of cabbage.

Production, Yield and Varieties on Collards during Spring of 1994, and Fall of 1993. The production, yield and varieties on collards during the Spring 1994 and Fall of 1993 are presented below:

Number of respondents: 2 Processors (Spring) and 2 Processors (Fall)

Total Acres contracted by these processors: 100 (Spring) and 290 (Fall)

Average number of collards acres per processor: 50 (Spring) and 145 (Fall)

Average yield of collards per acre: 7.9 tons (Spring) and 7 tons (Fall)

Varieties included: Champion.

Out of the four processors, two did not contract collards during the spring season of 1994. Detailed information on varieties planted, acres planted and average yield per harvested acre for the Spring and the Fall seasons are presented in Table XIII. Out of the three recommended varieties of collards for Oklahoma such as Vates, Champion and Georgia, only Champion was used. A total of 790 tons of collards was processed by these processors during the Spring of 1994.

During the Spring of 1994, the average yield of Collards was 7.9 tons per acre. It may be noted that in an area of 40 acres under one processor, the average yield was 10 tons per acre whereas in another area of 60 acres under another processor, the average yield per acre was 6.5 tons. It was not known with certainty why this variation occurred. Some of the possible causes could be soil quality (e.g. pH level), weather, cultural practices such as the crop being cut twice or more could lead to increased yields. So cultural practices possibly made the differences. However, during the Fall of 1993, a total of 2030 tons of collards was produced, and the average yield per acre stood at 7 tons. The average yield per acre under one processor was 6.2 tons whereas under another processor it was 12 tons.

TABLE XIII

PRODUCTION, YIELD AND VARIETIES ON COLLARDS

| Season | Variety Planted | Acres Planted | Acres Harvested | Average Yield Per Harvested Acre in Tons |
|---|---|---|---|---|
| Spring 94 | Champion | 40 | 40 | 10 tons |
| Spring 94 | Champion | 60 | 60 | 6.5 tons |
| Fall 93 | Champion | 250 | 250 | 6.2 tons |
| Fall 93 | Champion | 40 | 40 | 12 tons |

Insect Control - Use of Insecticides: As noted in Table XIV, 100 acres of land were used for collards production in Northeastern Oklahoma and the entire area under collards production (100 acres) was treated with insecticides during the Spring of 1994. The main insects were Loopers (Cabbage loopers) and Lep. Larvae (diamondback caterpillar larvae). Permethrin (Pounce), esfenvalerate (Asana), mevinphos (Phosdrin) were used to control these insects. Permethrin (pounce) proved to be 100 percent effective, while esfenvalerate and mevinphos were reported by one processor to be 90 percent effective. All insecticides were applied by commercial air. During the Fall of 1993, Permethrin was applied to 40 acres of collards, and control was considered by one processor to be 95 percent successful. Mevinphos, Permethrin and Diazinon were applied to 250 acres of collards and control was reported by one processor to be 90 percent successful.

TABLE XIV

USE OF INSECTICIDES ON COLLARDS

| Season | Insects | Acres Treated | Pesticides | No. of Applications | % of Control | Methods of Application | Applied By Whom |
|---|---|---|---|---|---|---|---|
| Spring 94 | Loopers | 40 | Permethrin | 1 | 100 | Aerial | Commercial |
| Spring 94 | Lep Larvae, Grass Hoppers | 60 | Esfenvalerate Mevinphos | 2 | 90 | Aerial | Commercial |
| Fall 93 | Loopers, | 40 | Permethrin | 1 | 95 | Aerial | Commercial |
| | Lep. Larvae, Grass Hoppers | 250 | Mevinphos, Permethrin, Diazinon | 2-3 | 90 | | |

Alternative Control Methods: Both processors who had collards grown for them indicated that no viable alternatives to insecticides were available to them to control insects. One processor indicated it was not known to them how they could withstand the attack of insects in the greens and spinach without insecticides and stated "we can't do without it". They were concerned that mevinphos was already withdrawn from the market. If permethrin were withdrawn they would not know what to use next. Alternative options if any were not known to them. Similar views about having no alternative control to combat insects were indicated by the other processor. All the processors also expressed concerns for the withdrawal of mevinphos. They were anxious to have some insecticide control measures to combat the attacks of insects. These views on alternative control measures are noted here because they are applicable to other greens as well. Yield losses, the processors indicated. varied from season to season.

Disease Control - Use of Fungicides: Of the two processors for collards, neither used any fungicides to control diseases in their crops during the Spring of 1994 and the Fall of 1993. No incident of diseases were reported by them. One of the processors, however, reported that most of the time fungicides did not show good results for them to cure diseases. It was noted by the processors that fungicides should be used as a last resort if all other cultural or similar alternative practices failed. Sometimes fungicides added problems instead of controlling or preventing disease the processors contended. This was in general applicable to collards, mustard and turnip greens.

Alternative Methods Used In Place of Fungicides to Control Diseases: In the total area of 100 acres of collards production, resistant varieties were used as an alternative to fungicides. Both processors mentioned resistant varieties of collards as an effective alternative to the use of fungicides to control diseases. One processor did not mention whether the use of alternative control methods such as resistant variety increased their cost of production. The other processor reported no increase in costs due to the use of resistant variety in collards production. Findings indicated that during the Spring of 1994, the processors did not use any fungicides to control disease for collards production. Therefore, alternative control methods served as an effective preventive measure against the outbreak of diseases.

As a cultural practice, one processor also used crop rotation every two years or every three to five years of collards production. One processor mentioned following corn - soybean - southern peas for one to two years in their crop rotation practice of collards.

It was observed by the processors that unless they got into a disease problem they did not rotate crops. The processors stated that the production period of collards and other greens as well, was too short to easily fit into a rotation sequence. The buyers to whom the processors supplied their products demand early delivery of the products. Because the growing period is too short, the producers usually could not opt for successive croppings after Spring greens or Fall greens. For example, after Spring greens, it is too late to grow corn. If the corn is grown, the crops may be lost due to frost. However, soybeans may be grown as a successive cropping. Further, though lease land may be available, farmers producing non-green crops may not be interested in leasing to producers growing greens. These findings agree with expert opinions (Motes, 1994). Therefore, this short period of harvest time prevented processors from using crop rotation as a major disease control alternative.

Weed Control - Use of Herbicides: Processors indicated that grass, broad leaf, careless grass (*Amaranthus graecizans*) and cocklebur (*Xanthium Pensylvanicum*) were the main weeds which competed with collards production. Those weeds were controlled by using Trifluralin. One ground application was made by the farmer and the control was considered by one processor to be 95 percent successful by one processor. Data on the application of herbicides to collards are depicted in Table XV.

TABLE XV

USE OF HERBICIDES ON COLLARDS

| Season | Weeds Attempted to Control | Acres Treated | Acres not Treated | Herbicides | No. of Applications | % of Control | Methods of Application | Applied by Whom |
|---|---|---|---|---|---|---|---|---|
| Spring 94 | Careless weeds, Cockle-bur | 40 | 0 | Trifluralin | 1 | 95 | Ground | Self |
| | Grasses, Broad Leaf | 50 | 10 | Trifluralin | 1 | 95 | Ground | Self |
| Fall 93 | Careless weed, Cockle-bur | 40 | 0 | Trifluralin | 1 | 95 | Ground | Self |
| | Grasses, Broad leaf | 250 | 0 | Trifluralin | 1 | 95 | Ground | Self |

Alternative Control Methods: None of the processors reported using any alternative control method to control weeds for the production of collards.

## Kale

Kale is hardy and lives over winter. It is known as a cool weather green. Out of 4 processors, only one processed kale. It is interesting to note that only 43 percent of the kale was harvested.

Production, Yield and Varieties of Kale during Spring of 1994 and Fall of 1993: Production, yield and varieties of kale, during the Spring of 1994 and Fall of 1993 are one presented below:

Number of respondents: 1 (Both Spring and Fall)

Total acres processed by these processors: 70 (Spring); 50 (Fall)

Total acres harvested: 30 (Spring); 50 (Fall)

Average yield of kale per acre: 3.5 tons (Spring); 8.6 tons (Fall)

Average number of kale acres per processor: 70 (Spring) and 50 (Fall)

TABLE XVI

PRODUCTION, YIELD AND VARIETIES OF KALE

| Season | Varieties Planted | Acres Planted | Acres Harvested | Average Yield Per Acres |
|---|---|---|---|---|
| Spring 94 | Premium | 70 | 30 | 3.5 tons |
| Fall 93 | Premier | 50 | 50 | 8.6 tons |

Insect Control - Use of Insecticide: During the Spring of 1994, 60 acres were treated with *Bacillus thuringiensis* var. *aizwai* and mevinphos to control lep. larvae (diamond back caterpillar) and aphids. Ninety-eight percent of the acreage was treated with insecticides. Two applications were made by commercial aerial applicators and the control was considered to be 90 percent successful. During the fall of 1993, all 50 acres under kale production was treated with insecticides *Bacillus thuringiensis* Berliner *Kurstaki*, mevinphos, and diazinon to control lep. larvae (diamondback caterpillar) and aphids. Two applications were made by commercial aerial applicators and the control was considered to be 90 percent successful by one processor (Table XVII).

Alternative Control Methods to Insecticides: As reported by the processors, there were no alternatives available to control insects on kale. Therefore, no alternative control measures were used.

TABLE XVII

USE OF INSECTICIDES ON KALE

| Season | Insects Attempted to Control | Acres Treated | Acres not Treated | Pesticides Used | No. of Applications | % Control | Method of Applications | Applied by Whom |
|---|---|---|---|---|---|---|---|---|
| Spring 94 | Lepidop-terous Larvae, Aphids | 60 | 10 | *Bacillus thuringiensis* var *aizwa*, Mevinphos | 2 | 90 | Aerial | Commercial |
| Fall 93 | Lepidop-terous Larvae, Aphids | 50 | 0 | *Bacillus thuringiesis* Berliner kurstaki, Mevinphos, Diazinon | 2 | 90 | Aerial | Commercial |

Disease Control - Use of Fungicides: The processor growing kale reported Downy Mildew, (*peronospora parasitica)* as a disease for this crop. Maneb was used to control downy mildew. As indicated in Table XVIII, Maneb was applied by commercial aerial applicators. Two applications were made and control was considered by one processor to be 80-90 percent successful.

TABLE XVIII

USE OF FUNGICIDES ON KALE

| Season | Diseases Attempted to Control | Acres Treated | Acres Not Treated | Fungicides | No. of Applications | % of Control | Methods of Application (aerial of ground) | Applied by Whom: |
|---|---|---|---|---|---|---|---|---|
| Spring 94 | Downy Mildew | 60 | 10 | Maneb | 2 | 80-90 | Aerial | Commercial |
| Fall 93 | None Used | | | | | | | |

Alternative Control Methods to Fungicides: One processor used a resistant variety (as reported by a processor), Premier on all 70 acres as an alternative to fungicides. However it was observed that despite the use of a resistant variety, plants were attacked by downy mildew. This phenomenon further testified that some resistant varieties were not effective to withstand the attacks of diseases. No other alternative control was mentioned by either processor.

Weed Control - Use of Herbicides on Kale: One processor indicated that grasses and broad leaf weeds were the principal weeds for kale. These two groups of weeds caused serious problems. To control these weeds, Trifluralin was used on 71 percent of kale crop during the Spring of 1994. As indicated in Table XIX Trifluralin was applied by ground and control was considered to be 95 percent successful.

TABLE XIX

USE OF HERBICIDES ON KALE

| Season | Weeds Attempted to Control | Acres Treated | Acres Not Treated | Herbicides Used | No. of Application | % of Control | Methods of Application | Applied by Whom |
|---|---|---|---|---|---|---|---|---|
| Spring 94 | Grass, Broad leaf weeds | 50 | 20 | Trifluralin | 1 | 95 | Ground | Self |
| Fall 93 | Grass, Broad leaf weeds | 50 | 0 | Trifluralin | 1 | 95 | Ground | Self |

## Mustard

Mustard is a quick growing half-hardy crop and is very rich in vitamins.

Production, Yield and Varieties of Mustard during Spring of 1994 and Fall of 1993: The production, yield, and varieties of mustard during the Spring of 1994 and Fall of 1993 are presented below:

Number of Respondents: 2 Processors (Spring and Fall)

Total acres contracted by these processors: 540 (Spring) and 240 (Fall)

Average number of mustard acre per processor: 270 (Spring); 120 (Fall)

Average yield of mustard per acre: 6.23 tons (Spring); 11.5 (Fall)

Varieties planted: Southern Giant Curled, Florida Broad Leaf, Savana and Slowbolt.

In the Spring of 1994, mustard was grown in 540 acres under contract with two processors, whereas during the Fall of 1993, only 240 acres of mustard were grown (Table XX). Though varieties such as Slobolt, Southern Giant Curled, Florida Broad Leaf and Tendergreen were recommended for Oklahoma (Motes, et al.1991), only Southern Giant Curled, Florida Broad Leaf, Slobolt and Savana were planted in the survey area. Yield per harvested acre varied from

5.9 tons to 10 tons. The average yield was 6.23 tons per acre in the Spring of 1994 and 11.5 tons per acre in the Fall of 1993.

TABLE XX

PRODUCTION, YIELD AND VARIETIES OF MUSTARD

| Season | Varieties Planted | Acres Planted | Acres Harvested | Yield Per Harvested Acre |
|---|---|---|---|---|
| Spring 94 | Southern Giant Curled | 40 | 40 | 10 tons |
| | Savana | 500 | 450 | 5.9 tons |
| Fall 93 | Savana, Florida Broad Leaf | 200 | 200 | 11 tons |
| | Slo bolt | 40 | 40 | 14 tons |

<u>Insect Control-Use of Insecticides</u>: Both processors used insecticides to control insects. *Mevinphos* and *Bacillus thuringiensis* var. *aizwai* were applied to 500 acres of mustard to control aphids i.e. green peas aphids (*Myzus persica* (*Sulzer*), lepidopterous larvae i.e.diamondback caterpillar (*Plutella xylostellar (linnaeus*) and loopers i.e. cabbage loopers (*Trichoplusia ni (Hubner*). Agree (*Bacillus thuringiensis var. aizwai*) was applied to 40 acres to control loopers. Lepidopterous larvae and aphids i.e. green peas aphids (*Myzus persica (Sulzer)* were controlled in 500 acres of turnip greens using *Bacillus thuringiensis var. aizwai* and mevinphos. *Bacillus thuringiensis* Berliner var. *kurstaki* (Biobit), Diazinon, *Bacillus thuringiensis* var. *aizwai* and mevinphos were applied by commercial aerial applicators (Table XXI) during the Fall of 1993. In some fields two applications were made, whereas in others only

one application was made. Control of insects was considered to be 90 percent and 95 percent successful in 500 acres and 40 acres of mustard, respectively during the spring of 1994. Table XXI portrays a detailed comparative picture of the use of insecticides during the Fall of 1993 and Spring of 1994.

TABLE XXI

USE OF INSECTICIDES ON MUSTARD

| Season | Insects Attempted to Control | Acres Treated | Acres Not Treated | Pesticides Used | No. of Applications | % of Control | Methods of Application | Applied by Whom |
|---|---|---|---|---|---|---|---|---|
| Spring 94 | Loopers | 40 | 10 | *Bacillus thuringiensis* var *aizwai,* Mevinphos | 1 | 95 | Aerial | Commercial |
| | Aphids, Lep. Larvae | 500 | 0 | *Bacillus thuringiensis* var. *aizwai, Mevinphos* | 2 | 90 | Aerial | Commercial |
| Fall 93 | Loopers | 40 | 0 | Cycloate | 2 | 95 | Aerial | |
| | Grass-hoppers Lep. Larvae | 200 | 200 | Biobit, Diazinon, Mevinphos | 2-3 | 90 | Aerial | Commercial |

It was found from the survey that the entire acreage of mustard production was attacked with insects during the Spring of 1994. In some areas only loopers i.e. cabbage loopers (*Trichoplusia ni (Hubner* )were prevalent whereas in other areas both aphids i.e. green peas aphids (*Myzus persica (Sulzer*) and lepidopterous larvae i.e. diamond back caterpillar (*plutella xylostellar* (linnaeus) were a serious threat. In the Fall of 1993, Grasshoppers, Lep. Larvae and Loopers caused damage to mustard.

Alternative Control Methods: Both the processors indicated that there was no alternative method available to control insects in mustard crop.

Disease Control-Use of Fungicides: Of the two processors contracting mustard in 540 acres, neither used any fungicide. However, during the Spring of 1994 fungicides did not provide acceptable control when used. Instead, cultural practices such as cutting the mustard in time (cutting greens three to four times) helped prevent diseases, they contended.

Alternative Control Methods: Results of this survey indicated processors used alternative methods such as crop rotation, as well as other cultural practices, such as cutting mustard three to four times during the season to combat white spot disease. A total of 130 acres was used in crop rotation. All the greens followed a coherent pattern of crop rotation. For example, after cultivating mustard for three to five years they rotated corn-soybean-southern peas for one to two years. Crop rotation as indicated by the processors was not a very feasible option to solve pest problems. Sometimes crop rotation was not economical. The processor reported that crop rotation was not always a viable option as an alternative control method details of which were discussed earlier under collards production.

Weed Control-Use of Herbicide: Weeds caused a threat to the cultivation of mustard. As noted before, the total area of mustard production in the Spring of 1994 was 540 acres, and 490 acres were harvested. But weeds such as grass weeds, broad leaf weeds and Johnson grass competed with the mustard crop. According to the respondents, to control those weeds they used Trifluralin on 440 acres, which comprised 91 percent of the acres under mustard crop. Trifluralin was applied once with ground equipment by the farmer (Table XXII) and two applications were made. Control of weeds was considered by one processor to be about 90 percent successful for 400 acres. However, percent of weed control was not mentioned for 40 acres.

During seedling period, Johnson grass needs to be eradicated or well managed so that it cannot stand as a threat to the normal growth of the greens. If Johnson grass is not controlled fully, it will not only compete with the greens under cultivation, but also will create serious problems for the next crops.

TABLE XXII

USE OF HERBICIDES ON MUSTARD

| Season | Weeds Attempted to Control | Acres Treated | Acres Not Treated | Pesticides Used | # of Applications | % of Control | Methods of Application | Applied by Whom |
|---|---|---|---|---|---|---|---|---|
| Spring 94 | Careless weeds, Johnson grass | 40 | 0 | Trifluralin | 1 | 95 | Ground | Self |
| Spring 94 | Grasses, Broad Leaf | 400 | 100 | Trifluralin | 1 | 95 | Ground | Self |
| Fall 93 | Grasses, Broad Leaf | 200 | 0 | Trifluralin | 1 | 95 | Ground | Self |
| Fall 93 | Careless weeds, Johnson grass, Cocklebur | 40 | 0 | Trifluralin | 1 | 90 | Ground | Self |

Alternative Control Methods. None of the respondents mentioned using any alternative control method to herbicides for the production of mustard.

Turnip Greens

Turnip greens grow fast. Turnip greens discussed here are not root crops. They are greens which are processed by the processors.

Production, Yield and Varieties of Turnip Greens during the Spring of 1994 and Fall of 1993: The production, yield, and varieties of turnip greens during the Spring of 1994 and the Fall of 1993 are presented below:

Number of respondents: 2 processors (Spring and Fall)

Total acres planted by these processors: 620 in the Spring of 1994 and 640 in the Fall of 1993

Average yield of turnip greens per acre: 11.5 tons in the Fall of 1993 and 8.27 in the Spring of 1994

Varieties planted: Alltop

Average number of turnip greens acres per processor: 310 in the Spring and 320 in the Fall.

According to the survey data, during the Spring of 1994 the average yield of turnip greens was 8.27 tons. During the Fall of 1993, average yield per acre of turnip greens was 11.5 tons. Though varieties such as Crawford, Seven Top, Alltop, Shogoin, Just Right (White), Purple Top, and White Globe were recommended for turnip greens production, only Alltop was used. Perhaps due to method of harvest such as cutting practices, there was a wide variation of yield per acre on turnip greens. It was found that yield per acre varied from 6.9 tons to 14 tons in the Spring of 1994, though the same variety was used. Data on production, yield and varieties of turnip greens during the Spring of 1994 vis-a-vis the Fall 1993 are presented in Table XXIII.

TABLE XXIII

PRODUCTION, YIELD AND VARIETIES OF TURNIP GREENS

| Season | Varieties Planted | Acres Planted | Acres Harvested | Average Yield per Harvested Acre |
|---|---|---|---|---|
| Spring 94 | All Top | 120 | 120 | 14 tons |
| | All Top | 500 | 500 | 6.9 tons |
| Fall 93 | All Top | 120 | 120 | 14 tons |
| | All Top | 520 | 520 | 10.5 tons |

Control of Insects-Use of Insecticides: As can be observed from Table XXIII, both the processors used insecticides to control insects in their turnip greens production. In the Spring of 1994, turnip greens were produced on 620 acres; insecticides were applied to 580 acres to control loopers, (cabbage loopers) lepidopterous larvae i. e. diamondback caterpillar larvae (*Plutella Xylostellar* (Linnaeus), and aphids i. e. green peach aphids *(Myzus persica* (Sulzer). Insecticides *Bacillus thuringiensis var. aizwai* was applied to 80 acres to control loopers, while mevinphos and permethrin were used in another 500 acres to control aphids and lepidopterous larvae during the Spring of 1994.

During the Fall of 1993, 640 acres were planted and harvested, and insecticides *Bacillus thuringiensis var. aizawai*, diazinon and permethrin were applied to 600 acres of turnip greens to control grasshoppers, lepidopterous larvae (diamondback caterpillar) and loopers (cabbage loopers). During the Spring of 1994, Mevinphos, permethrin, and *Bacillus thuringiensis* var. *aizawai* were applied by commercial aerial applicators. Two applications of insecticides by commercial aerial applicators were made for 500 acres and one application was made for 80 acres. The control was considered to be 95 percent effective for 500 acres. However, for 80 acres, control reported was 95 percent successful. During the Fall of 1993 Mevinphos, permethrin, *Bacillus thuringiensis* var. aizawai and diazinon were applied by commercial aerial applicators. Two applications were made for 520 acres and one application was made for 80 acres and control was considered by processors to be 90 and 100 percent successful respectively (Table XXIV).

Alternative Control Methods to Control Insects: None of the processors mentioned the use of any specific alternative control measure to combat insects. As pointed out earlier, the processors indicated that at the present no alternative control measure was available to them to control insects on any greens and spinach.

TABLE XXIV

USE OF INSECTICIDES ON TURNIP GREENS

| Season | Insects Attempted to Control | Acres Treated | Acres not Treated | Pesticides Used | No. of Times Applied | % Control | Methods of Application | Applied by Whom |
|---|---|---|---|---|---|---|---|---|
| Spring 94 | Lepidopterous Larvae, Aphids, | 500 | 0 | Mevinphos Permethrin | 2 | 90 | Aerial | Commercial |
| | Loopers | 80 | 40 | Bacillus thuringiensis var. aizawai | 1 | 95 | Aerial | Commercial |
| Fall 93 | Lepidopterous Larvae, Grasshoppers | 520 | 0 | Mevinphos Permethrin Diazinon | 2 | 90 | Aerial | Commercial |
| Fall 93 | Loopers | 80 | 40 | Bacillus thuringiensis var. aizawai | 1 | 100 | Aerial | Commercial |

Control of Weeds-Use of Herbicides: Like any other greens, turnip greens had to compete with weeds such as grasses, broad leaf, and cocklebur (*Xanthium Pensylvanicum*) for its normal growth. Trifluralin was used to control those weeds. As noted from the survey report during the Spring of 1994, Trifluralin was applied to 430 acres of turnip greens to control cocklebur. Control was considered to be 95 percent successful for all 430 acres. Data on the use of herbicides on turnip greens in the Spring of 1994 and Fall of 1993 are presented on Table XXV. During the Fall of 1993, 600 acres were treated with Trifluralin to control *Xanthium pensylvanicum* (cocklebur).

Alternative control methods to Herbicides: None of the processors mentioned using any kind of alternative control measure in place of herbicides for the control of weeds in turnip greens.

Disease Control-Use of Fungicides: One processor did not use any fungicide either in the Spring of 1994 or in the Fall of 1993. The other processor used Benomyl. As observed from Table XXVI, Benomyl was applied in the Spring of 1994 on 400 acres of turnip greens to control

TABLE XXV

USE OF HERBICIDES ON TURNIP GREENS AND METHODS OF APPLICATION

| Season | Weeds Attempted to Control | Acres Treated | Acres Not Treated | Herbicides | No. of Applica-tion | % of Control | Methods of Application | Applied by Whom |
|---|---|---|---|---|---|---|---|---|
| Spring 94 | Cocklebur, Johnson Grasses | 80 | 40 | Trefluralin | 1 | 95 | Ground | Self |
| | Grasses, Broad Leaf | 350 | 150 | Trefluralin | 1 | 95 | Ground | Self |
| Fall 93 | Cockle-bur, Weeds | 80 | 40 | Trefluralin | 1 | 95 | Ground | Self |
| | Grasses, Broad-leaf | 520 | 0 | Trefluralin | 1 | 95 | Ground | Self |

white spot. One application was made by the commercial aerial applicators. The control of disease was considered by the processor to be 80-90 percent successful. Data on the usage of fungicides in the Spring of 1994 and the Fall of 1993 are presented in Table XXVI.

Alternative Control Methods: One processor used alternative control methods such as crop rotation on 200 acres to control white spot. Disease control increased by 10-20 percent after the application of this method. But at the same time cost increased by 20 percent. The other processor who did not use any fungicide did not also mention the use of any specific alternative practice.

TABLE XXVI

USE OF FUNGICIDES ON TURNIP GREENS

| Season | Disease Attempted to Control | Acres Treated | Acres Not Treated | Fungicide | No. of Applications | % Control | Methods of Application | Applied by Whom |
|---|---|---|---|---|---|---|---|---|
| Spring 94 | White Spot | 400 | 240 | Benomyl | 1 | 85-90 | Aerial | Commercial |
| | | | | | | | | |
| Fall 93 | White Spot | 350 | 290 | Benomyl | 1 | 85-90 | Aerial | Commercial |

Types of Pests Causing Greatest Money Loss

Over the Last Five Years (1989-1993)

In response to questions about pests which caused the greatest money loss for greens and spinach over the last five years, the answers of the respondents were diverse. Some processors mentioned a single pest, while others mentioned multiple pests causing damage to their crops. Results of their responses are presented separately for each crop. Table XXVII is presented in a summary form describing answers.

Spinach: The main types of pests that caused the greatest money loss for spinach are as follows.

1. Insect: One processor mentioned seed corn maggot (*Delia platura* (Meigen) while the other one noted aphids (green peach aphids (*Myzus persica* (Sulzer) to cause the greatest money loss for spinach. One of the respondents, who did not grow spinach in the study area in the Spring did not name any specific insect that caused damage to their spinach crop. It may be noted that this respondent grew spinach in previous years (in this geographic area). So, responses from that processor for the question on pests causing the greatest damage over the past five years were considered.

TABLE XXVII

TYPES OF PESTS CAUSING GREATEST MONEY LOSS
FOR GREENS AND SPINACH

| CROPS | INSECT | DISEASE | WEED |
|---|---|---|---|
| Collards | Aphids, Loopers | Anthracnose, Downy Mildew, Cercospora Leaf spot | Cocklebur, Pigweeds |
| Kale | Aphids, Loopers | Black rot, Cercospora Leaf Spot | Pig weeds |
| Mustard | Aphids, Loopers | Anthracnose, Cercospora leaf spot White spot | Cocklebur |
| Spinach | Aphids, Seed Corn Maggots | White Rust | Sibara, Henbit |
| Turnip Greens | Aphids, Loopers | Anthracnose, Cercospora leaf spot White spot | Cocklebur |

2. Disease: One hundred percent of the respondents (operating in the study area) mentioned White rust (*Albugo occidentalis*) as the disease which caused the greatest money loss for spinach.

3. Weeds: For one processor, sibara (Sibara *Virginica*) was the weed which caused the greatest money loss, and for another processor it was henbit (*lamium amplexicaule)*.

<u>Collards</u>: The main types of pests that caused the greatest money loss for collards are as follows.

1. Insect: Fifty percent of the respondents mentioned loopers i.e. cabbage loopers (*Trichoplusia ni* (Hubner) as an insect causing the greatest money loss for collards. Similarly, aphids i. e. green peach aphids (*Myzus persica* (Sulzer) caused the greatest money loss to another 50 percent of respondents. So the probability of causing the greatest money loss by these insects were equally likely.

2. Disease: Fifty percent of the respondents mentioned downy mildew (*Peronospora parasitia*) and another fifty percent noted, anthracnose (*Colletto trichum*), and cercospora leaf spot

(*Cercospora brassicae*) as diseases which caused the greatest money loss over the last five years for collards.

3. Weeds: While 50 percent of the respondents mentioned Pigweed (*Amaranthus spp.*) another 50 percent noted Cocklebur (*Xanthium pensylvanicum*) as weeds causing the greatest money loss for collards.

Kale: The main types of pests that caused the greatest money loss for kale are as follows.

1. Insects: The respondent mentioned aphids (*Myzus persica* (Sulzer) and loopers i.e. cabbage loopers (*Trichoplusia ni* (Hubner) as insects causing the greatest money loss for kale.

2. Disease: The processor mentioned blackrot (*Alternaria spp.*), and cercospora leaf spot (*Cercospora brassicae*) as the diseases causing the greatest money loss for kale.

3. Weeds: Pigweed (*Amaranthus spp.*) and Cocklebur (*Xanthium spp.*) were noted by the respondent as the weeds causing the greatest money loss for kale.

Mustard: The main types of pests that caused the greatest money loss for mustard are as follows.

1. Insect: Fifty percent of the respondents named aphids (*Myzus persica* (Sulzer) as an insect which caused the greatest money loss to mustard crop while loopers i.e. cabbage loopers (*Trichoplusia ni* (Hubner) did the same to the remaining 50 percent of the respondents.

2. Disease: For mustard crop, while White spot (*Pseudocercosporella capsellae*) caused the greatest money loss for 50 percent of the respondents, Cercospora leaf spot (*Cercospora brassicae*) and Anthracnose (*Colletotrichum*) did the same for the remaining 50 percent.

3. Weeds: One hundred percent of the respondents described cocklebur (*Xanthium pensylvanicum* ) as the weed which caused the greatest money loss for mustard production.

Turnip Greens: The main types of pests that caused the greatest money loss for turnip greens are as follows.

1. Insects: As in the case of other greens 50 percent of the respondents mentioned aphids (*Myzus persica* (Sulzer) as an insect causing the greatest money loss for turnip greens. Likewise, another 50 percent indicated loopers (*Trichoplusia ni* (Hubner) to have caused the greatest money loss for them.

2. Disease: Fifty percent of the respondents mentioned white spot (*Pseudocercosporella capsellae*) as a disease which caused the greatest money loss for turnip greens. Similarly, cercospora leaf spot (*cercospora brassicae*) did the same to the other fifty percent respondents.

3. Weeds: All the respondents pointed out cocklebur (*Xanthium pensylvanicum* L.) as a weed which caused the greatest money loss for turnip. However, due to short crop season for turnip greens and mustard, cocklebur was not in fact a very big problem, reported one half of the respondents. However, the recurring problem which causes damage is due to the leftover seeds of cocklebur from previous seasons and/or the seed production of small cocklebur plants in the Fall.

Scouting

In response to the questions concerning which method was most commonly used to determine pest control scheduling, as for example, if pesticides were needed, all the respondents mentioned scouting. Field men working for the processors performed regular scouting. Fifty percent of the respondents replied scouting was done once a week, twenty five percent replied at least twice a week and still another 25 percent mentioned that scouting was a continuous process for them. During scouting the field men and the farmers watched for insects, weeds, and diseases.

In response to questions on how much time it took to scout a 10 acre field, 50 percent replied 30 minutes, 25 percent indicated 15 minutes, and 25 percent indicated 60 minutes. One of them, however, indicated that it took the same amount of time whether one scouted a 10-acre field, or a field with less or more than 10 acres. In addition, expert opinions were also sought concerning timing needed to scout a ten acre field. Based on vast field experience, professional, and technical expertise, some scientists indicated that twenty minutes was an average time period needed to scout a ten acre field (Edelson, 1994). Edelson also indicated that the same time would be required to scout a twenty acre field of greens and spinach.

## Soil Fertility Tests

In response to the question on the frequency of soil fertility tests for collards, kale, mustard and turnip greens, 50 percent indicated that soil was tested annually while another 50 percent mentioned that it was done every 3-5 years. For spinach the responses were as follows: Thirty three percent indicated that soil testing was done when growers felt it was right to do so; another 33 percent reported that soil testing was done every two years; and the remaining 33 percent indicated that it was done within a period of 3 to 5 years.

## Crop Rotation

In response to questions on rotating greens with other crops, 50 percent indicated they rotated crops every two years, while another 50 percent indicated they rotated within 3-5 years with a frequency of rotation of 1-2 years. But they also indicated that they could not always practice crop rotation due of the following reasons (opened ended answer):

1) scarcity of land (25 percent indicated this)

2) greens were short period crops which stood as an obstacle to crop rotation (25 percent indicated this).

3) unless one got into a disease or any other pest problem one did not consider crop rotation as an option (25 percent indicated this).

4) hard to follow rotating corn with greens because of trash problems (50 percent indicated this).

5) crop rotation to control pests is not a feasible option (25 percent indicated this). The patterns of crop rotation are presented in Table XXVIII.

TABLE XXVIII

CROP ROTATION PRACTICES

| Crops | Crops Used in Rotation | Frequency of Rotation |
| --- | --- | --- |
| Collards | Corn<br>Soybean<br>Southern Peas | 1-2 years (50 percent)<br>2 years (50 percent) |
| Kale | Corn<br>Soybean<br>Southern Peas | 2 years (100 percent) |
| Mustard | Corn<br>Soybeans<br>Southern Peas | 1-2 years (50 percent)<br>2 years (50 percent) |
| Spinach | Corn<br>Soybean<br>Southern Peas<br>Corn - Squash | 1-2 years (33 percent)<br>2 years (34 percent)<br>2 years (33 percent) |
| Turnip greens | Corn<br>Soybean<br>Southern Peas | 1-2 years (50 percent)<br>2 years (50 percent) |

Alternative Control Methods/Practices Used, Integrated Pest Management (IPM) and Trends of Using Pesticides During 1990-94

In response to questions on the use of the alternative control methods for pesticides, responses were distributed as follows. Sixty-seven percent responded as having no serious problems of insect population in spinach cultivation during the Spring of 1994. But most of the respondents also said they used crop rotation every 2-3 years. Thirty-three percent of the respondents cultivating more than 90 percent of spinach production, however, indicated that they suffered from serious insect problems. It was also mentioned by them that to control insects in greens no suitable alternative control method was available.

To control weeds in spinach, hand hoeing and hand pulling were effective measures as stated and practiced by all the respondents. But they indicated that hand hoeing and hand pulling was expensive. Estimates of increase of costs as listed by the processors varied from 30 to 40 percent to 200 percent. To control diseases of spinach such as white rust (*Albuzo occidentalis*), resistant varieties and crop rotation were used by all. Sometimes a delay in planting date in the Fall season served as a method to control pythium rot disease in spinach. All the respondents wished to have a new resistant variety against diseases and insects on spinach. Though this study was mainly related to the Spring of 1994 of pesticides in the production of greens, many observations relating to alternative control and pest problems of previous years were also given by some producers. Processors indicated that alternative practices do not change from year to year. Moreover, at present there were no suitable alternative control measures to insecticides for all greens and spinach. To control weeds for kale, collards, mustard, and turnip greens there were no effective and economic alternatives in place of herbicides. This view was observed by 100 percent of the respondents for kale. Some respondents further indicated that Spring grass "could probably be controlled without herbicides." But their performances/alternative practices did not justify that observation. It should be remembered that alternative methods were used in combination with pesticides. Though IPM was considered to be a good measure to control pests, the processors did not specify adoption of IPM in their pest management schedule.

## Cost Effectiveness of Integrated Pest Management

In response to the question on the cost effectiveness of IPM to control pests, the responses were as follows: somewhat effective 50 percent, extremely effective 25 percent and very effective 25 percent. However, 25 percent of the respondents mentioned, as a remark, that the significance of IMP to them was a reduction in the use of pesticides. Some processors also observed that the definition of IMP was not clear to them.

Advantages and Disadvantages of Integrated

Pest Management

To answer the open ended question on the advantages and disadvantages of IPM, the respondents indicated the following:

Advantages:

1) Lowers cost (50 percent)

2) Encourages scouting (50 percent)

3) Minimizes safety hazards (25 percent)

4 Increases yield and increases profit (25 percent)

5) More efficient (25 percent)

6) Appeals to public (25 percent)

7) Less use of pesticides (25 percent)

8) Environmentally safe (25 percent)

Disadvantages:

1) Labor intensive (50 percent)

2) High degree of variability (25 percent)

3) Potential for lower yields (25 percent)

4) Increases cost (50 percent)

5) It takes more time (50 percent)

6) It outweighs the advantages (25 percent)

7) It is not a cut and dry method (50 percent)

Trends on the Use of Pesticides

In response to questions regarding the trends on the use of pesticides during the last 5 years (1990 - 1994), the respondents' answers were diverse. The figures within parenthesis in

Table XXIX indicate the percentage of respondents indicating the particular response (but not the percent of increase, decrease stayed the same).

TABLE XXIX

TRENDS ON THE USE OF PESTICIDES DURING 1989-1994

| Herbicides | Insecticides/Nematicides | Fungicides/Nematicides |
|---|---|---|
| Increased (25 percent) | Increased (25 percent) | Increased (25 percent) |
| Decreased (25 percent) | Decreased (50 percent) | Decreased (50 percent) |
| Stayed the same (50 percent) | Stayed the same (25 percent) | Stayed the same (25 percent) |

During the last five years, the overall use of herbicides did not increase. Seventy-five percent of the respondents indicated that the use of herbicides either stayed the same or decreased. Twenty-five percent of the respondents mentioned that the use of herbicides decreased, while another 50 percent of the respondents revealed that their herbicide usage stayed the same. It was observed from the survey that 25 percent of the respondents indicated that usage of insecticides increased. Fifty percent mentioned that usage of insecticides decreased, while another 25 percent of the respondents listed that its use decreased.

With regard to the opinions on the use of fungicides, 25 percent of the respondents indicated that usage increased. In contrast to this, 50 percent respondents noted that the use of fungicides decreased, while the other 25 percent pointed out that the usage stayed the same. Those who indicated that the use of fungicides stayed the same further mentioned under comments that they did not use any fungicides during the last few years. Ineffectiveness of fungicides to correct the diseases was cited by some processors as possible reasons of not using any fungicides. To quote,, "fungicide is not doing any good to us". Sometimes the use of fungicides did as much damage as the diseases did to the crops, asserted one processor. Not only that, the processor also indicated that fungicides never corrected the disease problem. Moreover, some respondents also mentioned that if the greens are cut regularly, then many of the disease problems could be avoided. As observed by this group of respondents (25 percent), greens would grow 1 ton per acre per day. So it was necessary to cut them at regular intervals when they were ready. "Failing to do so will lead to many problems as that of an old man who faces many problems" contended one of the processors.

Opinions of Processors About the Oklahoma Cooperative Extension Service

In response to the question on "what one thing the processors would like the Oklahoma Cooperative Extension Service (County Extension Agents) and IPM Area Specialists to accomplish in the next two years to help improve the business of the processors," the following suggestions were given by the respondents:

1) For spinach, come up with a white rust and blue mold resistant plant
2) Find economic and cheap method of production
3) Help growers learn to be more efficient producers of all their crops
4) Need more participation for a movement towards a breeding program
5) On the ongoing extension programs by the Oklahoma Cooperative Extension Service, joint participation by the producers and experiment field personnel should be practiced.
6) Make the growers understand the problems processors are facing regarding the safety standard of pesticide usage as per government regulations.

In response to the question on what the processors would like to tell about the future use of pesticide on greens, the respondents' comments were:

"We need pesticides. Greens cannot be grown without them. But educate the growers to use pesticides as minimum as possible."

"Educate the growers about scouting and as such avoidance of using more pesticides".

"At this point in time each crop under this survey (collards, kale, mustard, spinach and turnip greens) lacks a herbicide, fungicide and insecticide for controlling one pest or another. However, we are losing pesticides quicker than we are going to get new ones. Furthermore, consumers are allowing less and less defects."

The processors revealed that this scenario put them into a difficult problem to continue their business. One processor also contended that withdrawal of some insecticides might put them out of business and the price of the greens might go up as the production will be lowered substantially.

# CHAPTER V

# SUMMARY OF FINDINGS, CONCLUSIONS, RECOMMENDATIONS AND IMPLICATIONS

The main purpose of the study was to determine the usage of pesticides on greens by the food processors in Northeastern Oklahoma and also cultural or alternative practices followed. An auxiliary purpose of this study was to document the availability of alternative control methods in place of pesticides. The idea behind this was that unless the views of the field level personnel involved in the production were known, no recommendations or regulations about the use of pesticides or its alternatives would be effective. This study, therefore, attempts to search those viewpoints vis-a-vis the current usage of pesticides on greens in Northeastern Oklahoma.

## Objectives of the Study

The objectives of this study were to:

1) determine number of acres of greens and spinach and varieties planted, harvested and average yield per acre obtained;

2) determine number of acres treated with pesticides and types of pesticides used (insecticides, herbicides and fungicides);

3) determine methods of application of pesticides;

4) identify pests which caused the greatest money loss;

5) determine the trends of pesticide usage during 1990-1994;

6) determine alternative control methods used including cultural practices to control pests (insects, diseases and weeds);

7) determine methods of monitoring fields against pest (scouting);

8) determine views on Integrated Pest Management (IPM);

9) determine what food processors' would like the Oklahoma Agricultural Cooperative Extension Service (County Extension Agents)and IPM Area Specialists to accomplish to help improve their business.

## Procedures

The population of this study consisted of all the four food processors who process greens (collards, kale, mustard, turnip greens and spinach) in Northeastern Oklahoma. A written sample questionnaire was distributed to all these food processors at the Ozark Food Conference, Springdale, Arkansas on April 6th and 7th, 1994. The survey was designed to collect information on planting and harvesting the greens, uses of pesticides and alternative control methods practiced. The entire population (i.e. four food processors) responded to the survey. Twenty seven greens and spinach growers were contracted by these processors. However, growers were not surveyed. One processor did not have spinach grown (processed) in the Spring of 1994, although it did in the Fall of 1993. Another processor did not have spinach grown at all. One processor had all the five crops grown for them . Another processor had only collards, mustard and turnip greens grown for them. Usage of pesticides by the processor who did not have spinach grown in the Spring of 1994 was not accounted for in this study. But views expressed by that processor on the alternative practices, especially IPM, and trends of pesticide usage during the last five years (other than Spring 1994) were included. After the initial meeting with the food processors at Springdale, AR, telephone contacts were made to visit with them at their convenience. On scheduled dates interviews were conducted . Some of them filled out the questionnaires and answered questions in face to face interviews. The rest of them, however, answered the questionnaires through face to face interviews only. Some of the questions were not answered, so that respondents' views on those questions could not be obtained. To conduct this survey an instrument was developed and then reviewed by an advisory committee as well as the experts in the field. Content, construct and face validity were completed for the instrument through the multiple review process. To address each of the objectives established in the study nineteen items were developed in two sets of questionnaires.

## Summary of Findings

The respondents of this survey were all the food processors of greens and spinach in Northeastern Oklahoma. Their production figures were different from the figures published by the U.S. Census of Agriculture, because the census considered yield for both seasons and also the production of growers who supplied the fresh market greens and spinach. If overwintered spinach production was included, it was also found that spinach had the highest acrages under green production. But if over wintered prodution (spinach) is not included, then turnip greens would occupy the top place in terms of both highest acres planted and per acre yield received among greens and spinach production either in the fall or in the spring. Per acre yield on the greens and spinach varied widely from processor to processor. The main reason for this variation was cutting practices of the processors . The processors who cut the greens three to four times received more yields.

### Objective One: Determining Production, Varieties and Yield Information

A total of 1943 acres of greens and spinach was cultivated for the food processors in Northeastern Oklahoma in the Spring of 1994. The total number of acres harvested was 1648. Total production of greens and spinach stood at 9588 tons.

Collards: A total of 100 acres of collards was planted for two processors in the Spring of 1994, whereas during the Fall of 1993, total acres planted were 290. The average yield of collards was 7.9 tons per acre during the Spring of 1994. The average per acre production of collards between processors varied from 6.2 tons to 10 tons . The total production of collards was estimated to be 790 tons during the Spring of 1994, which was 8 percent of total greens and spinach production. Champion was the only variety of collards grown in Northeastern Oklahoma. An auxiliary survey was also made for all the greens and spinach for previous years and seasons. But data for all greens and spinach were not complete. However, for collards, a complete figure was obtained. In the Fall of 1993, 290 acres of collards were planted and harvested, and the average yield was 7 tons per acre which varied from one processor to another processor. Total production stood at 2030 tons and average yield was 7 tons per acre. However, the average yield per acre from processor to processor varied from 6.2 tons to 12 tons.

Kale: Production of kale during the Spring of 1994 and the Fall of 1993 stood at 105 tons and 430 tons respectively. A total of seventy acres was planted and only 30 acres were harvested in the Spring of 1993. The average yield was 3.5 tons per acre. Premier was the only variety used for kale production. The harvested area of kale consisted of 42 percent of the total acres planted in kale. In the Fall of 1993, 50 acres were planted and harvested with an average yield of 8.6 tons per acre. Yield in the Fall was higher than the Spring.

Mustard: In the Spring of 1994, Savana and Southern Giant Curled varieties of mustard were grown on 540 acres. A total of 490 acres were planted and harvested with an average yield per acre of 6.23 tons which varied from 5.9 tons to 10 tons.

During the Fall of 1993, 240 acres were planted and harvested using Florida Broad Leaf, Savana and Slow bolt with an average yield per acre of 11.5 tons which varied from 11 tons to 14 tons.

Turnip Greens: Using the Alltop variety, a total of 620 acres was planted and harvested with an average yield per acre of 8.27 tons in the Spring. The average per acre yield from processor to processor varied from 6.9 tons to 14 tons. In the Fall of 1993, 640 acres were planted and harvested. The average yield per acre of turnip greens varied from 10.5 tons to 14 tons.

Spinach: Four hundred and ninety three acres were planted in Spinach in the Spring of 1994, of which 408 acres were harvested with an average per acre yield of 2.33 tons. Avon, Coho, Chesapeake and Hi-pack varieties were used for the cultivation of spinach. During the Fall of 1994, 396 acres were planted and 330 acres were harvested using Fall greens, Chesapeake, and unnamed variety 424 with an average yield per acre of 3.55 tons. It was found that average yield in the Fall was higher than in the Spring.

Observations: The yield of spinach in the Spring of 1994 seemed low. Total area under production in greens and spinach differs from other literature such as U.S. Agricultural Census because in that census an entire year of production was considered. This study focused on the Spring of 1994. An auxiliary survey provided some data on the production, yield and varieties of the greens and spinach during past few years. Supplementary surveys on the greens and spinach revealed that production of over-winter spinach was higher than that in the Spring or Fall. Similarly in cases of the greens, production was higher in the Fall than in the Spring.

## Objective Two: Determining Acres Treated and Types of Pesticides Used

The findings of this survey indicate that there is extensive use of pesticides in the production of the greens and spinach. It was found that 76.24 percent of the acres under the greens and spinach production in the Spring of 1994 in the survey area were treated with insecticides. Similarly for the same crops, use of herbicides and fungicides accounted for 59.24 percent and 36.20 percent of the acreage respectively.

The Oklahoma study provides evidence that on the whole, the use of herbicides was less than the overall norms as evidenced in the U.S. consumption data on pesticides.

Types of pesticides used included: *Bacillus thuringiensis* var. *aizawai*; *Bacillus thuringiensis* Berliner.*kurstaki*; Diazinon; Mevinphos; Permethrin; Benomy; Metalaxyl; Maneb; Trifluralin; Cycloate; Phenmediphan.

In some cases multiple insecticides such as Agree, Biobit, Diazinon and Phosdrin; or Biobit, Diazinon and Pounce; or Biobit, Diazinon and Phosdrin were applied to the same acres.

Objective Three: Determining Methods of Pesticide Application

In general, the trend of application of pesticides was similar to general patterns of pesticide application in the U.S. Both ground and aerial applications of pesticides were made. To control insects, all the insecticides such as *Bacillus thuringiensis* var. *aizawai*, *Esfenvalerate*, Mevinphos, and Permethrin were applied through commercial aerial applicators. On the average the number of aerial applications used to apply insecticides stood at 1.63. One hundred percent of the applications were done by the aerial application method. It was found that, unlike insecticides, herbicides for all the areas under the greens and spinach cultivation were applied by ground application. This was done by the processors' own certified applicators.

Similarly, fungicides were applied by ground application to 23 percent of the area treated with the fungicides. The aerial application method covered the remaining 77 percent. It may be noted that while calculating percentages of ground or aerial methods of application of pesticides, only a total area treated with a particular pesticide was taken into consideration. For example, if the same land was treated by two or more applications or by different categories of pesticides, the percentage was not calculated based on 2 or more number of applications or use of different pesticides in the application. A breakdown of the method of application of pesticides for each crop is depicted in Table XXIX.

TABLE XXIX

METHODS AND NUMBER OF APPLICATIONS OF PESTICIDES USED

| Pesticides Applied | Crop | Method of Application | Average Number of applications | Applied by |
|---|---|---|---|---|
| Insecticides | Collards | Aerial | 1.5 | Commercial |
| | Kale | Aerial | 2 | Commercial |
| | Mustard | Aerial | 1.5 | Commercial |
| | Spinach | Aerial | 2 | Commercial |
| | Turnip greens | Aerial | 1.5 | Commercial |
| Herbicides | Collards | Ground | 1.5 | Self |
| | Kale | Ground | 1 | Self |
| | Mustard | Ground | 1 | Self |
| | Spinach | Ground | 1 | Self |
| | Turnip greens | Ground | 1 | Self |
| Fungicides | Collards | None | None | None |
| | Kale | Aerial | 2 | Commercial |
| | Mustard | None | None | None |
| | Spinach | Aerial | 1 | Commercial |
| | Turnip greens | Ground<br>Aerial | 1<br>1 | Self<br>Commercial |

Objective Four: Determining Pests Causing the Greatest Money Loss

The processors were asked to indicate which pests caused the greatest money loss over the last five years for each crop they grew. The survey indicated that all of them were aware of the accurate pest identification problem as a first step/measure in planning an efficient control program.

Insects: Fifty percent of the respondents identified aphids as the insects that caused the greatest money loss for all the greens, while the remaining half recognized loopers. For spinach, while one half pointed out aphids as the cause of the greatest money loss, the other half did mention seed corn maggot as a serious insect causing loss of crops. But in terms of total acres contracted, the respondents having seed corn maggot as an insect problem, processed less than one percent of the total spinach acres in the survey area. In summary, aphids, loopers and seed corn maggot caused the greatest money loss over the last five years for each crop under the survey.

Diseases: Anthracnose, cercospora leaf spot and downy mildew caused the greatest money loss for collards. Black rot caused the greatest loss for kale. Fifty percent of the respondents contracting ( processing ) about 99 percent of total mustard, and about 80 percent of total turnip greens singled out white spot as the greatest killer. The rest identified anthracnose and cercospora leaf spot as causing the most damage to collards, mustard and turnip greens. Disease causing the most financial loss to the processors was white rust.

Weeds: With respect to collards production, pig weeds and cocklebur each respectively caused the most financial damages to fifty percent of the respondents. For kale production, pigweed caused the most damage. All the respondents pointed out cocklebur as the weed that brought the most financial loss for turnip greens and mustard. Data on pests that caused the greatest money loss for the crops (greens and spinach) during 1990-1994 are presented in Table XXX.

The common pests that the producers attempted to control are presented in Table XXXI.

Objective Five: Determining Trends of Pesticide Usage During 1990-1994

With a view to determining the trends of pesticide usage, the processors were requested to indicate an estimate on trends during the last five years (1990-1994) in insecticides/nematicides, herbicides and fungicides.

TABLE XXX

PESTS CAUSING THE GREATEST MONEY LOSS FOR THE GREENS AND SPINACH, OVER FIVE YEARS, 1990-1994

| Crops | Insect | Disease | Weed |
|---|---|---|---|
| Collard | Aphids, Loopers | Anthracnose, Downy mildew, (Cercospora Leaf spot) | Cocklebur, Pigweeds |
| Kale | Aphids, Loopers | Black rot, Cercospora Leafspot | Pig weeds |
| Mustard | Aphids, Loopers | Anthracnose, Cercospora Leafspot, White spot | Cocklebur |
| Spinach | Aphids, Seed Corn Maggots | White Rust | Sibara, Henbit |
| Turnip Greens | Aphids, Loopers | Anthracnose, Cercospora Leaf spot, White spot | Cocklebur |

TABLE XXXI

COMMON PESTS IN THE GREENS AND SPINACH PRODUCERS ATTEMPTED TO CONTROL

| Crops | Insects | Diseases | Weeds |
|---|---|---|---|
| Collards | Lep.larvae, Grass hoppers, Loopers | No specific disease | Grasses, Broad Leaf, Johnson grass, Cocklebur |
| Kale | Aphids, Lep.larvae, Grasshoppers, Loopers | Downy mildew | Grasses Broad Leaf, Cocklebur |
| Mustard | Aphids, Lep.larvae, Grasshoppers, Loopers | White spot, Bacterial | Cocklebur, Grasses, Broad Leaf |
| Spinach | Beetles, Lep.larvae, Grasshoppers, Seed Corn Maggots | White Rust, Pythium Rot | Sibara, Shepherd Purse, Grasses, Broad Leaf, Henbit, May Weed |
| Turnip Greens | Aphids, Lep.larvae, Grasshoppers, Loopers | White spot | Grasses, Broad Leaf |

Insecticides/nematicides: Twenty five percent of the respondents indicated an increase in the use of insecticides; fifty percent mentioned a decrease while the remaining twenty five percent contended that it stayed the same. The estimate, at least, indicated that there was a decrease in overall usage of pesticides.

Herbicides: Twenty five percent of the respondents indicated that use of herbicides increased, another 25 percent mentioned decreased usage, and the remaining half (50 percent) indicated that it stayed the same. This finding on herbicide usage revealed that there was no marked increase in the usage of herbicides.

Fungicides: Twenty five percent of the respondents pointed out that there was an increase in fungicide usage; 50 percent indicated a decrease in usage, while the remaining 25 percent mentioned that it stayed the same. Among the 25 percent of the respondents who indicated that usage of fungicides remained the same, comments were made that they did not use fungicides during the past few years. In the absence of yearly data of pesticide usage in those years (from 1990 to 1994), no good estimate can be given on the percent increase, decrease, or no change trends (stayed the same). Data for the Fall of 1993 and the Spring of 1994 for all the respondents were available. The data revealed that use of insecticides stayed the same. But for herbicides and fungicides there was a decrease in usage.

## Objective Six: Use of Alternative Control Methods

There was an intent to determine the past and current alternative practices such as crop rotation, use of resistant variety, row spacing, early or late planting, etc. being practiced by the processors. The processors were asked questions on the greens and spinach to indicate what alternative control methods they were using to control pests, besides the use of pesticides. The responses on the whole were encouraging. All the respondents used some kind of alternative control method such as crop rotation whenever possible.

Insecticides: For some crops no alternative control methods were available. This example, of course, is situation based. For example, 33 percent of the respondents indicated that there existed no alternative for insect control and they were having problems with insects for all the greens and spinach. On the contrary, 67 percent indicated having no serious problems with insects. This was especially true for spinach. For other crops, half of the respondents indicated having no alternatives to control insects, the remaining half, however, did not mention anything about alternative control methods but indicated that they really needed insecticides to control insects. The processors expressed deep concern for the cancellation of Phosdrin (mevinphos) and indicated that if Pounce (permethrin) is banned or withdrawn, then at this time they did not know what they would use or how they would continue their business. Their personal opinions revealed that all of them were well aware of the adverse effects of pesticides, but at the same time they wanted some sure ways of controlling pests. They considered themselves as risk averters.

Herbicides: Like that of insecticides, there existed no alternative control method in place of herbicides to control weeds in collards, kale, mustard and turnip greens according to the processors. All of the processors thought that there were alternative methods available only for spinach production such as hand hoeing and hand pulling to control weeds. However, one of the respondents indicated that the Spring weeds probably were not a serious problem. But no similar comments were made for the Fall weeds.

Fungicides: Perhaps, among the pesticides, fungicides could be replaced by some alternative control measures. This observation was evident from the respondents' cultural practices and similar other methods to combat diseases using alternative control methods in place of fungicides.

Soil Testing. Soil is a very important factor in any crop production. Soil fertility also determines suitability of crop rotation practices. The processors, as such, were requested to answer how often they conducted soil fertility tests. The responses of half of the respondents who produced collards, mustard and turnips indicated that soil fertility testing was done every three to five years. The other half of this group did their soil fertility testing annually.

Processors' responses about soil fertility testing for spinach producing fields were as follows: "when growers feel" (33 percent); three to five years (33 percent). For kale also, the soil fertility test was done every three to five year period.

Crop rotation as an alternative to using insecticides was practiced by all in the survey area. The frequency of rotation varied from one to two years. A special comment on crop rotation was that all the respondents indicated crop rotation was not an economically feasible alternative to insecticides and it was expensive to adopt. Some of them also indicated that crop rotation such as corn with greens was hard to follow because of trash problems. Moreover, with greens being a short period crop and land for the production of greens being scarce, and an early demand from the buyers for the processed products from the supplier hindered crop rotation practice. However, some of the processors also kept the fields fallow for one to two seasons. This was indicated by some of the respondents as a special comment on crop rotation. Moreover, due to short harvesting period and the unwillingness of some farmers to swap lands for diversified crop production, successive croppings could not be followed. In addition, after Spring greens, it is too late to grow corn. However, soybean can be grown after Spring greens, and it fits into crop rotation sequence and/or successive croppings. In summary, all the respondents practiced some cultural control such as crop rotation, variation of planting dates, and use of resistant variety. The rotation of crops also helped, as some observed, as a means of maintaining soil fertility.

Objective Seven: Determining Methods of Monitoring Pests

It was deemed very important to determine processors' perceptions regarding the practice of monitoring (scouting) fields for pests as an effective pest management practice. Therefore, they were asked to specify their most commonly used methods of determining pest control scheduling such as visible damage, pest numbers, scout report, calendar application (time of year), and applicator's recommendation.

<u>Insect control</u>: For insects, 75 percent indicated that they determined the pest control scheduling by observing pest numbers while the remaining 50 percent revealed that it was determined by scout reports. Since some respondents had more than one answer, the grand total of different methods of pest scheduling under each category such as insect, disease and weeds will not total to 100 percent.

<u>Disease control</u>: Fifty percent of the respondents stated visible damage as a method of determining whether pesticides were needed, while 25 percent mentioned scout report as their option. However, still another 25 percent did not specify any particular method, but as a special comment noted that watching for insects, weeds and diseases was a continuous process by the field men. These responses indicated that the processors used some good Integrated Pest Management practice. Although all the processors followed some kind of IPM practices, all the components of IPM were not practiced by the farmers contracted by processors to grow greens and spinach for them.

<u>Scouting</u>. To know the importance of scouting pests (insects, weeds, or diseases), the processors were also asked questions to indicate who did the scouting. The responses of the processors revealed that scouting occurred on 100 percent of surveyed processors' fields growing greens and spinach. Besides the farmers, the scouting was done in all cases by the processors' representatives. This finding confirms other studies such as RTD Updates: Pest scouting by the USDA Economic Research Service (1994) which indicated 92 percent scouting for pests in lettuce fields.

Similarly Vanderman et al. (1994) mentioned that about 74 percent of all vegetable acres were scouted for diseases and weeds. For spinach, about 96 percent of acreages was scouted.

Present study on greens and spinach, therefore, confirms findings of the previous studies about the practice of scouting.

As the frequency of scouting is very important for any pest control measure, processors were also asked how often they did scouting on their fields. Fifty percent of the respondents indicated that they did pest scouting once a week, while the other half reported performing the same at least twice a week. One of the respondents indicated that scouting was done at least six times a season through visible damage. The main source of scouting for pests was the field man of the processors as well as farmers.

To get an idea of the cost of scouting, the processors were asked to indicate how long it took to scout a 10 acre field. The responses were as follows: 15 minutes (25 percent); 30 minutes (50 percent); 60 minutes (25 percent). One of them further indicated that the same amount of time was needed to scout a field for pests irrespective of size of field. This finding differs from some previous studies (Rabb, Todd and Ellis, 1976). According to Rabb, Todd and Ellis (1976) the expenses for scout salaries and travel stood at $4.70 per acre in 1973. They also mentioned that it was higher than other crops.

Findings of this survey on scouting a ten acre field also match the experts opinions. Edelson (1994), based on his personal and long field level experiences, indicated that it takes twenty minutes to scout a ten acre field of greens and spinach. He also revealed that the same time will be needed to scout a twenty acre field of greens. His professional expertise nearly matches the average time listed by the respondents of this survey.

In the 1989 annual report on New York Integrated Pest Management Program (Cornell University, 1990), it was reported that per acre cost for scouting service was $6.00. Eight growers who represented 75 percent of all major road side markets in the Southern section of New York who participated in a fresh market vegetable IPM program paid these expenses for scouting. However, if we consider the salary of a field man of the processor in this survey area to be $2000, then per acre cost for scouting pests (considering 30 minutes time spent on a 10 acre field) is less than 65 cents. This is not a conclusive finding but is interesting and provoking no doubt.

Objective Eight: Determining Views on Integrated Pest Management (IPM)

The planning and successful implementation of IPM will not be materialized unless all the actors associated with it fully endorse and/or practice this system. With that end in view the processors were asked to indicate their views on IPM practices from three perspectives: cost effectiveness, advantages and disadvantages.

The processors were asked to indicate the cost effectiveness of IPM on a sliding scale from extremely effective, very effective, somewhat effective and not effective. From this perspective the survey revealed that 50 percent of the respondents considered IPM as very effective, 25 percent viewed it as extremely effective and 25 percent perceived it to be somewhat effective. Some of them also made a special comment indicating that IPM was significant to them from the viewpoint that it tended to reduce use of pesticides. However, in terms of cost effectiveness, they rated IPM as somewhat effective. Some processors also indicated that there was confusion about the definition of IPM. As such, some of them felt that it was ambiguous to express their opinions on such an issue, when they were not sure of the definition. In their responses to the open ended question about the advantages and disadvantages of IPM, participants views were as follows:

Advantages: Lowers costs of production, minimizes safety hazards, increases yield, increases profit and decreases pesticide usage.

Disadvantages: Increases cost, consumes more time, not simple and inexpensive, disadvantages (especially taking more time) outweigh the advantages. As a special remark someone also mentioned that IPM was not a cut and dry method.

Objective Nine: Determining Value of Extension

Service and the Use of Pesticides in Greens

In an effort to determine how the Oklahoma Cooperative Extension Service and IPM Area Specialists could help the processors improve their business in the next two years, they were asked an open ended question to provide their suggestions. The responses from the processors were as follows:

- Come up with a white rust (*Al bugo occidentalis*) and Blue mold which is also known as downy mildew (*Peronospora effusa*) resistant variety.

- Provide economical way of production and farm management.

- For growing peas get some type of herbicides for goat heads.

- Educate the farmers through demonstrations on how crop rotations and other cultural practices could economically help them increase yield and also manage pests efficiently.

- Involve farmers in demonstration/experimental plots.

- Due to soil compaction, some farmers were caught in a cycle of poor plant growth and poor yield. They also did not practice crop rotation. Therefore, the farmers need help and guidance to remedy the situation.

- Educate the farmers to use appropriate amount of pesticides.

- Help growers learn to be efficient producers of all their crops.

The processors were also asked to represent their views on the use of pesticides in greens. In response to this open ended question the processors' suggestions/comments were:

- At this point in time each crop on this survey lacked a herbicide, fungicide and or insecticide for controlling one pest or another.

- They were losing pesticides quicker than they were gaining new ones. Furthermore, they indicated, consumers were pressing for less defects of products from a cosmetic standard hich created a conflict between the two - one from the consumers' side and the other from the processors' side.

- Let the farmers know the problems processors were facing regarding the various issues of pesticide usage, especially the public opinion about it and what they could do to keep the use of chemicals as minimum as possible without sacrificing any quality or quantity.
- Inform the farmers about horticultural practices which use less pesticides.

In addition, while discussing the pesticide issues, some of the processors made special comments related to farming. As perceived by them, the number of small farmers was going to decline because small farmers could not economically operate and manage their business while maintaining all the regulatory and other associated crop cultivation practices. On the other hand, the large farms could hire production managers and regulatory managers who could efficiently manage both quality and volume (quantity) of the products.

## Conclusions

An analysis of the data as presented in Chapter IV and the subsequent findings formed the basis for the following conclusions made in this study:

1. From the production and yield of greens and spinach, it is deduced that the Oklahoma still holds its position as one of the important green and spinach producing states. It was concluded that the processors represented all the greens and spinach producing areas of Northeastern Oklahoma, and they were very familiar with the production system and also had the opportunity to supervise the farming methods and practices of the producers who grew the crops for them under contract. However, acreages under greens and spinach production are going down.

2. The users of pesticides were neither indiscriminate nor careless. That the uses were probably judicious (not indiscriminate) is supported from the pest management practices of monitoring (scouting) the fields by the processors.

3. It was concluded that aerial spray constituted the main method of application of pesticide. Many authors including Pimentel (1978) viewed that aerial spray did not effectively reach the target group of pests.

4. From the findings, it was clear that the processors through their monitoring system determined which pests caused the greatest damage to their crops. They perceived that aphids, loopers and seed corn maggots were the most damaging insects to the greens and spinach, although downy mildew, black rot, white spot, white rust, cercospora and anthracnose were serious diseases. Many of these diseases could be controlled with less or no use of fungicide. Similarly, cocklebur, pigweed and sibara were the most harmful weeds. The processors recognized the pest problems. Effective and efficient measures to manage/control them is a priority for them.

5. Perhaps at this point, processors of the greens and spinach could not withstand the attacks of insects without the use of insecticides. The loss of greens production might be immense in the absence of insecticides. The observation of this finding revealed that to the processors there existed no alternatives to insecticides to control insects. The percent of insect control in some cases was also misleading. For example, Pounce and Phosdrin was used in the Spring to control grasshoppers which proved to be effective. But grasshoppers from Soybeans in the Fall re-infested the fields within 1-2 days. It was also concluded that although the use of herbicides is considered to be higher than that of insecticides and fungicides, the processors of greens and spinach took a step forward to gradually lower usage of herbicides. The use of herbicides in the survey area supports this conclusion. It was further concluded that processors made serious efforts to minimize the use of fungicides by not using any fungicides in the production of many greens. This conclusion matches with earlier reports by the USDA (1969) which found that the growers in the U.S. depended less on chemicals to control plant disease.

The processors could not go for viable production of the greens and spinach without some insecticides . This was evident from the usage pattern of pesticides and their feelings about it. The processors perceived the use of insecticides to be necessary to keep them in viable business. The pattern of usage of pesticides as perceived by them further led to the conclusion that the use of fungicides was decreasing without sacrificing higher yields and quality. In this context alternative control measures proved to be effective. Although the original and the oldest method of hand hoeing and hand pulling was practiced, the trends of usage of herbicides did not show a marked decrease.

Several studies as documented in the literature review indicated a somewhat downward trend in the usage of pesticides especially fungicides. The Northeastern Oklahoma study supports those earlier findings except those on insecticides.

6. From the findings it was clear that the processors had the willingness to adopt alternative control methods in place of pesticides. But they must be sure that those control measures would be efficient and cost effective to them. Benefit-Cost Analysis would play a major role in the application of alternative control methods. It was also apparent from the views and cultural practices adopted by the processors that the degree of importance placed on alternative agriculture as a production system and the considerations they would place on the rights of the forthcoming generations about the safety of the environment would play a deep role and as such have impact on the performance and adaptability of a system such as alternative agriculture.

However, some of the varieties of greens mentioned by the processors as resistant to diseases, and as such used by the farmers as alternative to fungicides were not really so (Damicone, 1994; Motes, 1994).

7. It was concluded that the processors and farmers were aware about monitoring fields against pests and pesticide. Application decisions were made from the viewpoint of economic thresholds based on scouting.

Pest damage to various green and spinach crops was a big management issue to the processors. All the respondents were very much concerned about the meticulous maintenance of pest control scheduling. It possibly helped them make their decisions on correct pest management strategy.

8. The processors generally cherished the idea that IPM would be cost effective and there existed potential of reduced usage of pesticides through the practice of IPM. But it also appeared that they were not too sure about it - especially the various definitions of IPM were not clear to them. The findings of this study did not, however, reveal whether environmental benefits of

reduced pest control measures influenced the processors to have multiple views on IPM. It was evident though that processors' economic bottom line of saving money not foregoing higher yield would motivate them in implementing of the ideas of IPM.

9. The processors were anxious to see the Oklahoma Cooperative Extension Service (County Extension Agents) and the IPM Area Specialists come up with an economically viable and commercially profitable production and farm management system. As a first step to this, they felt the necessity for developing resistant varieties with higher yields for crops such as spinach. They also concluded that there was an immense need to educate the farmers about the alternative control methods and to disseminate the results of field level research to the farmers about higher productivity and cost cutting methods including IPM and other related practices. Farmers also needed to understand the problems the processors were facing in terms of producing and marketing the greens and spinach. The processors further contended that the farmers must know the pressures and legal responsibilities processors face with respect to using smaller amounts of pesticides and thus making the environment safer for present and the future generations.

10. Last but not the least, "Pesticides are one of the most contentious elements of modern agriculture. Numerous citizens are concerned about their environmental and health effects, a concern which potentially affects the agricultural economy. The effect could come both through changes in the demand for agricultural products, such as increased demand for pesticide free fruits and vegetables, and through induced changes in regulatory actions, such as reduction in pesticide registration by the Environmental Protection Agency" (Horowitz, 1994, p. 396).

## Recommendations

Based on the opinions put forward by the respondents and the analysis of this study the following list of recommendations is made. These recommendations may help in a decision making process of alternative agricultural methods in general and use of less pesticides in particular.

1. Further efforts and research are needed for developing resistant varieties with higher yield for spinach in particular and other greens in general. Previous research (Wiggans, Marshall and Odell, 1963) indicated that Hybrid Basra and Dixi market generally produced high yields of spinach. An experimental study is needed to examine which varieties (Fall green, Chesapeake, AR-88-354 (breeding line), and Avon) produce highest yields. Scientists (Damicone, 1994) believe that varieties of spinach such as Avon, Coho, and AR-88-354 (breeding line) are resistant to white rust (Albugo *Occidentalis*), and downy mildew (*Peronospora Parasitica*); 424 (breeding line) is resistant to downy mildew (*Peronospora Parasitica*); Fall green is resistant to white rust, downy mildew, anthracnose and cucumber mosaic virus. But yet, white rust was an economically important disease problem. Motes (1994) indicated that spinach is not commonly infected by viruses.

Further, although some processors indicated use of varieties resistant to diseases for the production of collards (champion) and kale (Premier), plant pathologists (Damicone, 1994) think that at present there are no disease resistant varieties for greens. Similarly, there appear to be no resistant varieties of greens to weeds as well (Motes, 1994).

2. An information and technology transfer system of education on alternative agriculture based on extension principles should be developed and disseminated to the farmers. To make the program effective, the field personnel who are the key men of the processors for farm management and extension should also actively participate in this information dissemination process.

The successful case studies of alternative agriculture may be documented as videotapes and distributed to the County Extension Agents who would take further steps to bring this information to the growers as well as to the key personnel of the processors.

3. The processors were very familiar with safety issues of pesticides. Perhaps the same is true for the growers. But, safety knowledge could be improved. The growers must update the knowledge on nozzle replacements and sprayer calibration. Perhaps, the U.S. spraying quality of pesticides and also the pesticide applicators are among the best in the world. But, still there is room for improvement when it comes to the knowledge about efficient spraying of pesticides. This

is an important issue because correct knowledge on calibration not only reduces the cost of spraying pesticides, but it also helps save the environment from adverse effects of indiscriminate use of pesticides.

4. Suitable alternatives to insecticides for the greens and spinach should be demonstrated and communicated to the producers. In this process the choice of chemical alternatives to control pests would be based on the availability and relative efficiency of those alternatives be it cultural or reduced use of pesticides. Special management practices should be developed to control green peach aphids, cabbage loopers and seed corn maggots.

5. Further efforts by the processors, producers, cooperative extension personnel, and scientists are needed to reduce the use of pesticides, especially herbicides. Various reviews on literature demonstrated that implementation of higher cosmetic standards resulted in greater use of pesticides on food. But this extensive use of pesticides for cosmetic purposes is both detrimental to public health, environmental, as well as contrary to consumers demand. So effective measures are needed to investigate ways of reducing the amounts and frequency of the use of pesticides. For example, Morgan (1990) mentioned that the "Key to weed control without using herbicides is good management based on a knowledge of the crop and the weeds that are likely to cause trouble. To grow food successfully without herbicides the farmers need to look at some of traditional methods that were used before modern chemicals were introduced" (p. Introduction ii). The author clearly demonstrated that there are more substitutable alternative controls for herbicides than fungicides. However, results of this survey revealed that there was less use of fungicides.

6. The alternative control methods need to be viewed as an attitudinal approach which needs to be followed by the farmers/processors or the local people in general. It is also necessary to involve the public, especially, in the local community where the greens and spinach are grown in the choices of alternatives. Unless the options and implications of pesticide usages are fully understood by the growers, the consumers and the public in general who believe they have a say in the decision making process, alternative policy making may not be effective. Since it is a very

complex problem to achieve public confidence, extension agents, biologists, social scientists and the local community leaders need to work together with the growers and the processors.

7. Economic damage thresholds need to be specified more clearly to the farmers as well as to the fieldmen of the processors. Infestation levels within soils or crops may be sampled which may demonstrate how the pest population fluctuate and thus help farmers in proper pest management strategy. This is very much needed, because in the absence of determining economic damage thresholds through scouting, farmers may apply pesticides without knowing the density of pest attacks. This will lead to the misuse of pesticides.

8. Farmers and processor representatives should visit and participate in the demonstration and research fields on alternative agriculture including IPM managed by the Oklahoma Cooperative Extension Service Division. That would give processors and farmers first hand knowledge - seeing is believing.

Farmers also need information that will lesson their risks of making wrong decisions. It is further recommended that farmers and processors in cooperation with IPM Area Specialists should follow a strategy for reducing the use of pesticides in greens and spinach.

9. If alternative control method is viewed as a philosophy, not as a technical package for a safe environment and better agricultural practices with a viable business option, it will tend to be effective. There is also a need for the farmers to take an effective role in the evaluation of Extension services as well as evolution of technology, so that it can be adapted to suitable farming practices and/or alternatives. In this context, it needs to be mentioned that farmers are more interested in applied research results which provide them with specific knowledge about particular subjects to solve their problems (Bezdicek, 1994). Bezdicek also noted that scientists usually put a higher value on research that develops theories/research techniques. So Oklahoma Cooperative Extension should not forget the opinions of Bezdicek.

10. . There is a vital need for follow up studies for the present analysis. It is recommended that a follow up study about the usage of pesticides by the growers may be undertaken. This will help compare this study and the proposed study. Further, the proposed

follow up study will be useful, especially to determine if there existed any information gap on the uses of pesticides between the processors and the farmers. The proposed study should also contain issues on the use of fertilizers, use of pesticides during the last ten years (year wise) and whether farmers are considering adoption of IPM with lesser use of pesticides. Since the results of the survey indicated that the processors have sufficient technical knowledge and expertise, a study is also needed on the details of IPM practices by the farmers.

11. There is a need for improving farm management development programs (management practices). To accomplish this, a program implementation committee may be formed. This should include farmers, processors, extension workers, and scientists. The existing vegetable growers association may take a lead in this respect. This will facilitate ongoing contacts and exchange of ideas between vegetable growers themselves and also with researchers, scientists, policy makers, and cooperative extension services.

But it is emphasized that while practicing alternative systems, one should remember that for alternative systems to be successful and widely accepted, such methods must not either lead to insignificant profit margin or bring lower yields.

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APPENDIXES

# APPENDIX A

# QUESTIONNAIRE SET 1

# QUESTIONNAIRE SET 1

**Name of County: (If applicable)____________________**

**1. Please tell us your production and yield information for your 1993-1994 greens production.**

| Crop | Season | Varieties Planted | Acres Planted | Acres Harvested | Average yield per harvested acre |
|---|---|---|---|---|---|
| **Collards** | **Spring** | | | | |
| | **Fall** | | | | |
| **Kale** | **Spring** | | | | |
| | **Fall** | | | | |
| **Spinach** | **Spring** | | | | |
| | **Fall** | | | | |
| | **Over winter** | | | | |
| **Mustard** | **Spring** | | | | |
| | **Fall** | | | | |
| **Turnip** | **Spring** | | | | |
| | **Fall** | | | | |

2. Please identify the **FUNGICIDES** used to control diseases in your 1993-1994 green crops and related information..

| Crops | Season | Disease(s) you attempted to control | Acres treated | Fungicides (Brand Name) | Number of applications | Percent control % | Methods of application (aerial or ground) | Applied by whom : self or commercial |
|---|---|---|---|---|---|---|---|---|
| Collard | Spring | | | | | | | |
| | | | | | | | | |
| | Fall | | | | | | | |
| | | | | | | | | |
| Kale | Spring | | | | | | | |
| | | | | | | | | |
| | Fall | | | | | | | |
| | | | | | | | | |
| Mustards | Spring | | | | | | | |
| | | | | | | | | |
| | Fall | | | | | | | |
| | | | | | | | | |
| Spinach | Spring | | | | | | | |
| | | | | | | | | |
| | Fall | | | | | | | |
| | | | | | | | | |
| | Over winter | | | | | | | |
| | | | | | | | | |
| Turnip | Spring | | | | | | | |
| | | | | | | | | |
| | Fall | | | | | | | |
| | | | | | | | | |

3. Please identify the **insects and insecticides** used to control insects in your 1993-94 crops. A complete list of insecticides is available on the last page of the survey.

| Crops | Season | Insects you attempted to control | Acres treated | Pesticides (Brand Name) | Number of applica-tions | Percent of control % | Methods of applica-tion(Ground or aerial) | Applied by whom : Self or commercial |
|---|---|---|---|---|---|---|---|---|
| **Collard** | **Spring** | | | | | | | |
| | **Fall** | | | | | | | |
| **Kale** | **Spring** | | | | | | | |
| | **Fall** | | | | | | | |
| **Mustard** | **Spring** | | | | | | | |
| | **Fall** | | | | | | | |
| **Spinach** | **Spring** | | | | | | | |
| | **Fall** | | | | | | | |
| | **Over winter** | | | | | | | |
| **Turnip** | **Spring** | | | | | | | |
| | **Fall** | | | | | | | |

Now we would like to ask you some questions about **weeds** in your 1993-94 green crops.

4. Please list the **herbicides** used to control weeds in your 1993-94 crops. Please rate the percent of increase or decrease.

| Crops | Season | Weed(s) you attempted to control | Acres treated | Herbicides (Brand Name) | Number of applica-tions | Percent control % | Methods of applications : Aerial or Ground | Applied by whom : Self or commercial |
|---|---|---|---|---|---|---|---|---|
| Collard | Spring | | | | | | | |
| | Fall | | | | | | | |
| Kale | Spring | | | | | | | |
| | Fall | | | | | | | |
| Mustard | Spring | | | | | | | |
| | Fall | | | | | | | |
| Spinach | Spring | | | | | | | |
| | Fall | | | | | | | |
| | Over winter | | | | | | | |
| Turnip | Spring | | | | | | | |
| | Fall | | | | | | | |

APPENDIX B

QUESTIONNAIRE SET 2

# QUESTIONNAIRE SET 2

**Name of county (if applicable)**________________________

1. If you used **alternative control methods** in place of **Fungicides** to control **diseases** in your 1993-94 crops such as crop rotation, resistant varieties, row spacing, seeding rates then please list the alternatives. Please indicate the percent of increase or decrease.

| Crop | Season | Diseases treated | Alternative Control Method(s) Used (resistant varieties) | Acres Treated | # of times alternative control methods applied | Percentage change in disease control | Changes in % of cost from normal production system | Methods of applications | Applied by whom: commercial/ self |
|---|---|---|---|---|---|---|---|---|---|
| Collard | Spring | | | | | | | | |
| | Fall | | | | | | | | |
| Kale | Spring | | | | | | | | |
| | Fall | | | | | | | | |
| Mustard | Spring | | | | | | | | |
| | Fall | | | | | | | | |
| Spinach | Spring | | | | | | | | |
| | Fall | | | | | | | | |
| | Over winter | | | | | | | | |
| Turnip | Spring | | | | | | | | |
| | Fall | | | | | | | | |

2. If you used **alternative control methods** in place of **insecticides** to control **insects** of your crops in 1993-94, such as crop rotation, resistant varieties, row spacing, seeding rates then please list the alternatives. Please indicate the percent of increase or decrease.

| Crop | Season | Insects treated | Alternative control methods used (resistant varieties) | Acres treated | # of times control methods applied | Percentage change in weed control | Changes in % of cost from normal production system | Methods of application | Applied by whom : Self or Commercial |
|---|---|---|---|---|---|---|---|---|---|
| Collard | Spring | | | | | | | | |
| | | | | | | | | | |
| | Fall | | | | | | | | |
| | | | | | | | | | |
| Kale | Spring | | | | | | | | |
| | | | | | | | | | |
| | Fall | | | | | | | | |
| | | | | | | | | | |
| Mustard | Spring | | | | | | | | |
| | | | | | | | | | |
| | Fall | | | | | | | | |
| | | | | | | | | | |
| Spinach | Spring | | | | | | | | |
| | | | | | | | | | |
| | Fall | | | | | | | | |
| | | | | | | | | | |
| | Over winter | | | | | | | | |
| | | | | | | | | | |
| Turnip | Spring | | | | | | | | |
| | | | | | | | | | |
| | Fall | | | | | | | | |
| | | | | | | | | | |

3. If you used some **alternative control methods** in place of **herbicides** to control **WEEDS** in your 1993-94 crops such as biological, cultural practices (cultivation of weeds), crop rotation, row spacing, seeding rates. Please list the alternatives and also please check appropriate box. Please indicate the percent of increase or decrease.

| Crop | Season | Weeds You attempted to control | Alternative Control Method(s) Used (Cultivation) | Acres treated | # of times alternative control methods applied | Percentage change in weed control | Changes in % of cost from normal production system | Methods of application : | Applied by whom : self or commercial |
|---|---|---|---|---|---|---|---|---|---|
| Collard | Spring | | | | | | | | |
| | | | | | | | | | |
| | Fall | | | | | | | | |
| | | | | | | | | | |
| Kale | Spring | | | | | | | | |
| | | | | | | | | | |
| | Fall | | | | | | | | |
| | | | | | | | | | |
| Mustard | Spring | | | | | | | | |
| | | | | | | | | | |
| | Fall | | | | | | | | |
| | | | | | | | | | |
| Spinach | Spring | | | | | | | | |
| | | | | | | | | | |
| | Fall | | | | | | | | |
| | | | | | | | | | |
| | Over winter | | | | | | | | |
| | | | | | | | | | |
| Turnip | Spring | | | | | | | | |
| | | | | | | | | | |
| | Fall | | | | | | | | |
| | | | | | | | | | |

4. Please indicate which insect caused the **greatest money loss** over the last five years for each crop you grew. Please also indicate the type of disease and the type of weed likewise.

| Crops | Insect | Disease | Weed |
| --- | --- | --- | --- |
| Collard | | | |
| Kale | | | |
| Mustard | | | |
| Spinach | | | |
| Turnip | | | |

5. Please select your most commonly used method to determine pest control scheduling(i.e. if pesticides are needed)

| | Visible damage | Pest numbers | Scout report | Calendar application (Time of year) | Applicator recommendations |
| --- | --- | --- | --- | --- | --- |
| Insect | | | | | |
| Disease | | | | | |
| Weed | | | | | |

6. Who does the scouting ? ____________________

7. How often do you scout your field?

___ Once a week ___ Twice a month ___ At least twice a week

___ Once a month Others, please specify ____________

8. How long does it take to scout a 10 acre field?

________________________________________________

9. How often do you test for soil fertility?

| | Collards | Kale | Mustard | Spinach | Turnip |
|---|---|---|---|---|---|
| Annually | | | | | |
| Every two years | | | | | |
| Every 3 years | | | | | |
| Never | | | | | |
| Others | | | | | |

10. How often do you rotate your greens? Please list below the crop(s) that you rotate with greens and how often.

| Crops | Rotation | Crops used in rotation | Frequency of rotation |
|---|---|---|---|
| Collards | | | |
| Kale | | | |
| Mustard | | | |
| Spinach | | | |
| Turnips | | | |

Now we would like to know your views on Integrated Pest Management (IPM). IPM is an approach that employs a combination of techniques to control pests before their numbers or damage become economically important. These may include regular crop checks, chemicals, crop rotation, resistant varieties, and natural control like predators or parasites of destructive insects.

11. In your opinion how cost effective is IPM to you? Please check appropriate box.

☐ Extremely effective ☐ Very effective ☐ Somewhat effective ☐ Not effective

12. List / indicate advantages and disadvantages IPM as perceived by you. For example increased profit, increased yields, decreased profit, increased cost etc.

| Advantages | Disadvantages |
| --- | --- |
| ________________ | ________________ |
| ________________ | ________________ |
| ________________ | ________________ |
| ________________ | ________________ |

13. Please indicate your estimate on trends during the last five years in herbicides use per acre, insecticide/nematicides use per acre and fungicide/nematicide use per acre. Please check appropriate box.

| Herbicides: | Insecticides/Nematicides: | Fungicides/Nematicides: |
| --- | --- | --- |
| ☐ Increased | ☐ Increased | ☐ Increased |
| ☐ Decreased | ☐ Decreased | ☐ Decreased |
| ☐ Stayed the same | ☐ Stayed the same | ☐ Stayed the same |
| ☐ Comments (if any) | ☐ Comments (if any) | ☐ Comments (if any) |

14. What one thing you would like the Oklahoma Extension Service (County Extension Agent) and IPM area specialist to accomplish in the next 2 years to help you improve your business?

________________________________________

________________________________________

15. Is there anything else you would like to tell us about the use of pesticides in greens? If so, please use the space below for that purpose. Also any comments you wish to make that you think may help us in future efforts to collect pesticide use information in Oklahoma will be welcomed. Your contributions to this survey is greatly appreciated. Thank you for completing this survey.

________________________________________

________________________________________

If you want a copy of the summary from this survey, please check here: ☐

APPENDIX C

INSTITUTIONAL REVIEW BOARD APPROVAL FORM

# OKLAHOMA STATE UNIVERSITY
# INSTITUTIONAL REVIEW BOARD
# HUMAN SUBJECTS REVIEW

**Date:** 10-17-94 **IRB#:** AG-95-004

**Proposal Title:** A PESTICIDE USE SURVEY IN NORTHEASTERN OKLAHOMA

**Principal Investigator(s):** James P. Key, Shah A. Salam

**Reviewed and Processed as:** Exempt

**Approval Status Recommended by Reviewer(s):** Approved

APPROVAL STATUS SUBJECT TO REVIEW BY FULL INSTITUTIONAL REVIEW BOARD AT NEXT MEETING.
APPROVAL STATUS PERIOD VALID FOR ONE CALENDAR YEAR AFTER WHICH A CONTINUATION OR RENEWAL REQUEST IS REQUIRED TO BE SUBMITTED FOR BOARD APPROVAL.
ANY MODIFICATIONS TO APPROVED PROJECT MUST ALSO BE SUBMITTED FOR APPROVAL.

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Comments, Modifications/Conditions for Approval or Reasons for Deferral or Disapproval are as follows:

Signature: John H. Wyckoff Date: October 24, 1994

Chair of Institutional Review Board

VITA

Shahmd Abdus Salam

Candidate for the Degree of

Doctor of Education

Thesis: A SURVEY OF PESTICIDE USE IN GREENS AND SPINACH PRODUCTION IN NORTHEASTERN OKLAHOMA

Major Field: Agricultural Education

Biographical:

Personal Data: Born in Rangpur, Bangladesh, September 30, 1945.

Education: Graduated from Chilmari High English School, Rangpur, in March 1961; received Bachelor of Arts degree (Honours) in Economics from the University of Rajshahi in May of 1966; received Master of Arts degree in Economics from the University of Karachi, Pakistan in October of 1968; received Master of Business Administration degree in Finance from Oklahoma City University in August of 1987. Completed the requirements for the Doctor of Education degree at Oklahoma State University in May 1995.

Professional Experience: Research Associate, Research Department, United Bank Ltd, Karachi, Pakistan, November 1968 to May 1970; Officer United Bank Ltd, Dhaka, July 1970 to December, 1971; Officer Janata Bank, Dhaka, January 1972 to May 1972; Assistant Manager Janata Bank, Dhaka, June 1972 to October 1975; Manager Janata Bank, Dhaka, November 1975 to February 1977; Faculty Member, Janata Bank Training Institute, Dhaka, March 1977 to March 1984.

Specialty Area: Finance, Banking, Rural Development and Resource Economics Completed courses for the Ph.D. program in Agricultural Economics at Oklahoma State University.

Professional Organizations: American Agricultural Economics Association, Oklahoma Agricultural Economics Association and Bangladesh Institute of Bankers.

Honors: Recipient of Outstanding Academic Achievement Award in M.B.A. Program (1987); Academic Excellence Award (Dean's List, 1985); Talent Scheme Scholarship(1961-1963); Merit Scholarship (1963-1966).