A Review on the Development of Integrated Pest Management and Its Integration in Modern Agriculture

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ABSTRACT--- ***Different to the eradication method applied in traditional farming, the Integrated Pest Management (IPM) is a system for managing pests in agricultural production that employs multiple tactics in consideration of economic, environmental, ecological and human health impacts. This paper presents an overview of the important milestones in the development of the IPM philosophy, evolving from a specific level of pest control that focuses on suppression of target pests to a more eco-friendly and/or systems approach of pest management where a range of non-chemical options and judicious use of pesticides are utilized. Moreover, some main driving forces that led to the development of the philosophy are analyzed and evaluated, including pest resistance, adverse impacts on environment, biodiversity, ecosystems and human health, and public reactions. Finally, this paper describes how it has been embraced in modern agriculture. Recent technological advances in crop protection using computer aids in forecasting, biotechnology in producing resistant cultivars, semiochemicals, natural enemies, selective pesticides, traps cropping and habitat management are also reviewed as a new trend in modern crop protection.***

Keywords – Integrated pest management, Pest control, Pesticides, Pest resistance, Environment, Human health, Agriculture.

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1. INTRODUCTION

In agriculture, pest management would be one of the integral parts of crop protection in ensuring yields and quality. Pests can be defined as organisms such as weeds, insects, bacteria, fungi, viruses and animals which unfavourably influence human lifestyles (Kent, 1992). In crop production, pests induce decreases in productivity and quality of the products on the field as well as after harvest (Galea, 2010). Integrated Pest Management (IPM) implies an approach in which a combination of methods is used to manage the pest population with considerations of economic efficiency and environmental effects rather than an eradicative method which is used in traditional practices (Galea, 2010). This paper presents a review on the historical development of the IPM; motivating forces that lead to development of IPM philosophy; and finally the pursuit of this approach in modern agriculture.

2. DEVELOPMENT OF THE IPM

Along with the development of agriculture, crop protection has evolved from a specific level, which focused mainly on target pests, to a more integrative and/or systems approach. This has led to the introduction of IPM where other non-chemical methods were explored and utilized in consideration with socio-economic, environmental and agro-ecosystem impacts to sustain the whole production systems. The development of IPM can be recognized in distinct landmarks hereunder.

First, research and educational activities in identification and control methods of some economically important pests were initiated from early twentieth century. Thus, the concept "pest control" was introduced (Kogan, 1998). However, this might be the reason for turning scientists into formulation of measures with the only aim of pest suppression. For instance, synthetic organic compounds were introduced to control plant pathogens in 1930 (Dhawan & Peshin, 2009). Moreover, discoveries of insecticide properties of DDT; herbicide 2, 4-D; and dithiocarbamate fungicides during 1930s induced a so called "dark age of pest control" over the period of 1940s – 1960s (Kogan, 1998; Peshin *et al.*, 2009; Pimentel & Perkins, 1980), which implies the over reliance on chemical pesticides and its consequences.

Additionally, though "integrated control" concept was initially coined in 1959 (Anon, 1996) with the original broad idea where all ecological resources will be utilized to control insects in a permanent, satisfactory and economical manners (Smith & Allen 1959, cited in Kogan, 1998), confusion and/or misunderstanding of the concept would, however, be one of the reasons leading to a focus on insect control (Anon, 1996). Later publications, for example, narrowed down into defining as "applied pest control" with the main focus on combining chemical and biological measures (Kogan, 1998).

Consequently, the increasing use of pesticides resulted in various impacts regarding socioeconomics, environment and human health. For example, sevenfold of pesticides were used in Japan during 1960-1970, nonetheless no increase in yield could be observed (Emden & Peakall, 1996). Moreover, though the use of chemical insecticides in the United States increased 10 times during 1945-2000, crop losses from insect destruction, however, rose almost twofold from 7 to 13% (Pimentel, 2009; Pimentel *et al.*, 1992). These aftereffects would be explained by pesticide resistance of pests and destruction of natural enemies (Emden & Peakall, 1996; Peshin *et al.*, 2009). What's more, tremendous effects of pesticide misuses on human health and environment contamination were evident (Pimentel, 2009).

A turning point in environment movement could be dated back from 1962 when the book "Silent Spring" by Rachel Carson was published, which explored the effects of pesticide overuse on environment and non-target species (Briggs, 1990; Emden & Peakall, 1996; Pollock, 2001). Hence, public awareness was raised and thereby the concept "integrated control" became popular in both scientific literature and practice (Emden & Peakall, 1996; Kogan, 1998). The declaration[1] of United Nations conference on the environment and development in Stockholm (1972) might reflect this shift.

Interestingly, a term "protective population management", later called "pest management" was also as popular as "integrated control" in scientific papers during 1970s. Although there were some controversies in the terminologies and their underlying conceptual values, Smith and Van-den Bosh (1967) combined these two concepts as "integrated pest population management". And finally, the term "Integrated Pest Management" (IPM) was officially accepted by scientific community in 1972 (Kogan, 1998).

So far IPM have been proved as a suitable strategy gearing toward sustainable agriculture (Anon, 1996). There have been many successful models, where IPM was incorporated, in crop protection worldwide (Peshin *et al.*, 2009; Way & van Emden, 2000).Given the important role of IPM, the perfection of its definition is needed. According to Kogan (1998) there have been 64 definitions for IPM proposed. However, the recent definition[2] by Prokopy (2003) would be considered as a rational one since the multiple tactics are utilized. This means other measures such as cultural practices, biological methods, host-plant resistance and interference methods are also used besides chemical control. Emden & Peakall (1996) stated that chemicals are still needed in IPM strategy, however "just as a stiletto instead of a scythe". Accordingly, chemicals are only used when necessary, the central focus is on other methods. Moreover, control of all classes of pests implies that pest management not only focuses on the major pests but also the minor ones and their interactions. This would fit with the higher level of IPM as stated in Kogan (1998). Eventually, the consideration of economic and ecological effects denotes a systematic approach and thus the validity of IPM.

3. FACTORS THAT INDUCED THE DEVELOPMENT OF IPM PHILOSOPHY

The drivers for development of IPM philosophy would be defined as pest resistance to pesticides; negative environmental and ecological impacts due to the misuse of pesticides; and eventually public pressure.

First, pest resistance was observed as a result of the over reliance on chemicals and thus new approaches would be expected for a more sustainable management of pests. Emden & Peakall (1996) asserted that pest resistance is the main driver leading to development of IPM. Since 1950s, pest resistance to pesticides, outbreaks of minor pest and host-plant resistant breakdown occurred due to the intensive use of synthetic pesticides (Dent, 1995; NRC, 1986), resulting in economic loss for growers (VCE, 2005a). Two examples of Japan and the US above have well reflected the impact. Further, resistance of insects and mites increased considerably in recent decades (from 7 species resistant to DDT in 1938 to 447 species resistant to all important groups of insecticides by 1984) (NRC, 1986). Nevertheless, development of a new pesticides in response to pest resistance and/or outbreak is considered as time-consuming and expensive since it requires lengthy processes of research, development and registration (VCE, 2005b). Therefore, exploration of new management methods would be projected. Scientists started to study on genetic, ecological and operational risk factors to look for alternatives in dealing with pest problems (Jutsum *et al.*, 1998). In this sense, crop protection requires multidisciplinary studies, contributing to the development IPM philosophy.

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[1] Declaration of Stockholm conference (1972): "the capacity of the earth to produce vital renewable resources must be maintained and, wherever practicable, restored and improved" (Source: Emden & Peakall 1996).

[2] Definition of IPM by Prokopy (2003): "a decision-based process involving coordinated use of multiple tactics for optimizing the control of all classes of pests (insects, pathogens, weeds, vertebrates) in an ecologically and economically sound manner".

Second, as a result of the synthetic pesticide treadmill since 1940s, the world has experienced substantial impacts regarding environmental contamination, biodiversity losses and eventually human health effects. These have led to the strong public reactions, government and international organizations' actions. All of these factors would contribute to formulation of IPM philosophy as well. For instance, many authors have reported the degradation of environment and human health due to pesticide overuses, particularly in developing countries where toxic chemicals at level I and II are commonly used (Norton *et al.*, 2005). Furthermore, non-target species such as birds, mammals, fish and natural enemies have been killed (Briggs, 1990; Peshin & Dhawan, 2009; Pollock, 2001). This has reflected the losses in biodiversity. Richer (2002) (cited in Peshin & Dhawan, 2009) reported 26 million incidents of human pesticide poisonings with 220,000 deaths annually as another example of human health impact due to pesticide misuse.

For these reasons, interventions at national and international levels have been made to reduce chemical use and promote new strategies in plant protection. For example, banning of hazardous pesticides, pesticide legislation; reduction of incentives for developing chemical pesticides; long delay of pesticide registration at national level; and international cooperation and actions in environmental protection were reported in Emden & Peakall (1996). These efforts have therefore supported the development of IPM philosophy where systematic and sustainable approaches and available resources are employed.

4. INTEGRATION OF THE IPM IN MODERN AGRICULTURE

Recent technological advances in pest management and public awareness in terms of food safety and healthy living environment have led to the better integration of IPM in modern agriculture.

Huge achievements in technologies have made IPM an adequate approach in modern agriculture. According to Anon (1996), new technologies have supported IPM development and supported the better use of conventional techniques, in which more management options and preventive measures are available. For instance, advanced forecasting computer models have been used as a decision support system instead of simple tables or charts (Anon, 1996). Moreover, improvements in biotechnology have produced pest resistant cultivars, semiochemicals and natural enemies to control pests. More selective pesticides have been developed to reduced impact on non-target species. What's more, trap cropping and habitat management have been also introduced (Kogan, 1998). A successful model of IPM for rice pests in Southeast Asia, where broad-spectrum pesticides were given way to natural controls (Kogan, 1998), would be another example that illuminated the important role of IPM in modern agriculture.

Besides, the increasing public demands in terms of food safety and clean environment have brought about the better farming practices to address these demands (WI, 2010) and thus adoption of IPM would be indispensable gearing toward sustainable agriculture. According to Texas IPM Foundation (2010), IPM assists growers produce better quality food, providing better food safety standards. In addition, it helps sustain productivity and ecosystem with much less environmental degradation or toxic residues. For example, application of insecticides in cotton in Australia has decreased by 60-75% since adoption of IPM (Way & van Emden, 2000).

The policies and actions of governments and international agencies resulted from social pressure for adoption of IPM as an integral part of farming practices to search for "natural and/or environmentally friendly control methods" (Dent, 2000). Through the course of IPM development and application in the US, which was shown in the recognition of IPM by President Nixon (1972) and the Area-wide pest management program by President Clinton (1993), targeting to 75% of the whole nation's crops using IPM by 2000 (Kogan, 1998), the important role of IPM in modern agriculture has thus been attested. Additionally, the recent international partnership programs have been conducted in support of IPM adoption in crop protection worldwide. Particularly, the "Global IPM Facility" Program, co-sponsored by the Food and Agriculture Organization of the United Nations (FAO), World Bank, the United Nations Development Program (UNDP) and the United Nations Environment Program (UNEP), has been in operation since 1995 (Kelly, 2005). All of these activities would suggest that application and dissemination of the IPM in modern farming practices are indispensable.

5. CONCLUSION

In short, the historical development of the IPM has been reviewed through some important milestones. The IPM has been developed from a specific pest control method to a more comprehensive approach to pest management where the judicious use of pesticide is applied in consideration of economic, environmental and production sustainability facets. In addition, some main drivers, which have resulted in the development of IPM philosophy, have been evaluated, namely: pest resistance, negative impacts on environment, ecology and human health; and social pressure. Finally, the analyses of modern technologies applied in plant protection and public cognition for improved quality of life have demonstrated how the IPM has been embraced in modern agriculture.

Though there has been a slow progress of IPM adoption worldwide (Peshin *et al.*, 2009), successful models in combination with technological, advisory, educational and financial supports as well as awareness raising activities from governments and international agencies would suggest a wider application of IPM in the near future. Eventually, the term "bio-intensive IPM and "ecologically-based IPM" would be well understood among farmers of the developing world.

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