Pesticide Pressure on Insect and Human Population-A review

Abstract

It is estimated that the current 7 billion world population would increase by 70 million people year, or 30%, to reach 9.2 billion by 2050. It is anticipated that this increased population density will result in a 70% rise in the demand for food production. This increase is mostly attributable to shifts in emerging countries' dietary trends toward higher-quality foods, such as increased consumption of meat and dairy products and the growing use of cereals for animal feed. There isn't much more agricultural land available. Any growth will primarily come at the price of forests and other natural ecosystems that support wildlife, wild cousins of crops, and organic pest adversaries. Additionally, rather than producing food, more agricultural land will be used to create bio-based commodities like fiber and biofuel. As a result, we must produce food on even less area, with even less water, and with less energy, pesticides, and fertilizer than we do now. There is an urgent need for sustainable production at elevated levels in light of these constraints. Reducing the present output losses resulting from pests is a significant obstacle to agricultural productivity. This review covers pest-related crop losses worldwide, estimates of productivity linked to pesticide use, costs and benefits of pesticide use, chemical yield loss reduction strategies, biological and recombinant pest control methods, and the difficulties facing the crop protection sector. In deciding how pesticides will be used in agriculture in the future, the general public plays a crucial role. However, the external issues related to the impacts of pesticides on human and environmental health must also be addressed as long as there is a need for pesticide-based solutions to pest management issues and food security concerns.

Comment [mm1]: Add

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Introduction:

Over the past 50 years, the cumulative effects of the Green Revolution have allowed the world's food output to double. The number of humans on the planet has more than doubled to seven billion since 1960. The population is expected to rise by 30% by 2050, reaching around 9.2 billion people. The demand for food production is expected to rise by 70% due to the growing global population and developing countries' shifting preferences toward meat and dairy products (FAO 2009).

Globally,anaverageof35%ofpotentialcropyieldislostto pre-harvest pests (Oerke, 2005). Food chain losses are comparatively substantial in addition to pre-harvest losses (IWMI, 2007). Simultaneously, agriculture needs to supply the growing worldwide need for food, feed, fiber, biofuel, and other commodities derived from plants. There isn't much more area available for agriculture because doing so would primarily jeopardize forests, wildlife habitats, wild relatives of crops, and natural adversaries of agricultural pests.With these constraints, the better option is by far to increase productivity on current land and practice sustainable farming. Preventing waste at every stage of the food chain is also essential. The rise in output will coincide with a changing and less predictable climate, the need for lowering greenhouse gas emissions from agriculture, and the depletion or shrinkage of land and water supplies. While technology will certainly keep evolving manyofthekeystolong-termglobalfoodsecurity,thereisalotwecandotodaywithexistingknowledge.

In light of growing costs and expectations for environmental and human health, agriculture needs to become more profitable and productive while utilizing the finest combination of current technologies. Much of the improvement in yield per unit of area can be attributed to better management of (biotic) stress rather than an increase in yield potential. Reducing output losses due to pests, diseases, and weeds is one of the major challenges facing agricultural production today (Oerke and Dehne, 2004). The number of pesticides used worldwide has increased by 15–20 times, indicating a significant increase in crop protection (Oerke, 2005).

In many places, simplified agro-ecosystems that are more susceptible to pest assault have supplanted diverse ecosystems. These crops need to be protected from pests in order to maintain the high level of food and feed yield required to fulfill the growing demand from humans (Popp, 2011). Food security will be greatly enhanced by assisting farmers in losing less of their harvests, especially in the poorest nations where rural farmers strive for greater than self-sufficiency. For farmers, achieving food security is merely the first step toward greater economic independence (FAO, 2009).

The positive results of pesticide use demonstrate that pesticides will remain an essential component of the wide variety of technologies that can preserve and raise global living standards. While some alternative approaches might be more expensive than traditional chemical-intensive farming methods, these comparisons frequently overlook the significant costs that pesticide use has on the environment and society. It is also necessary to address the externality issues related to pesticides' effects on human and environmental health (National Research Council 2000).

Agricultural producers use pesticides worth about USD 40 billion annually on a global scale. Only 2% of the worldwide crop protection industry is accounted for by biopesticides (McDougall 2010). In highly industrialized, developed nations, farmers anticipate a four- or five-fold return on their pesticide investment (Gianessi and Reigner 2005; Gianessi and Reigner 2006; Gianessi 2009). If farmers continue to use pesticides despite lower economic benefits, should we be able to supply the world's food demands? Can the financial advantages of pesticide use be maintained by improved integrated pest management (IPM)? Between now and the year 2050, agriculture will face some of the biggest challenges in its history. These are just a few of the concerns that scientists and specialists in pest control are grappling with (Popp 2011).

1. Croplossestopests

Crop productivity may be increased in many regions byhigh-yielding varieties, improved water and soil management,fertilization and other cultivation techniques. An increasedyieldpotentialofcrops,however,isoftenassociatedwithhighervulnerabilitytopestattackleadingtoincreasingabsolute losses and loss rates (Oerke*et al.*1994). An average of35 % of potential crop yield is lost to pre-harvest pestsworldwide (Oerke, 2005).

Apart from the pre-harvest losses, an additional 35% are accounted wasted by transportation, pre-processing, storage, processing, packing, marketing, and plate waste losses along the entire food chain. Preventing waste at every stage of the food chain is crucial, in addition to lowering crop losses brought on by pests (Popp, 2011).

The evolution of interactions between farmers and pests predates conventional insecticides by thousands of years. Pests can affect crop productivity and farmers' net income, but they can also affect the availability of food and feed, the economies of rural areas, and even entire countries. This can be demonstrated by differentiating between different loss levels, such as direct and indirect losses or primary and secondary losses (Zadoks and Schein, 1979). Weeds reduce crop productivity because they compete with crops for inorganic nutrients (Boote *et al.* 1983). Crop protection has been developed to stop and lessen crop losses brought on by pests both in the field (pre-harvest losses) and in storage (post-harvest losses). In this paper, pre-harvest losses are the focusi.e.theeffectofpestsoncropproductioninthefieldandtheeffectofcontrolmeasuresapplied byfarmersinordertominimiselossestoanacceptablelevel(Oerke, 2005).

Examining the entire spectrum of agricultural pests and the composition and application of chemical pesticides to control pests in different conditions would be impossible. Likewise, an assessment of the composition and application of pesticides to control pests in different environments would be impossible. Crop loss assessments are crucial for identifying areas that require further attention, for farmer decision-making, and for government decision-making. In 1929, fungus infections and animal pests each contributed 10% to the loss of cereal yield, according to German officials. Animal pests and diseases decreased potato production by 5% and 25%, respectively. According to Morstatt (1929), diseases and animal pests caused 5% and 10% of the production decrease in sugar beet, respectively. According to Marlatt's 1904 estimate, pre-harvest losses in the United States caused by insect pests were rarely less than 10%. Post-harvest losses were later the subject of data releases by the US Department of Agriculture in 1927, 1931, 1939, 1954, and 1965 (Cramer, 1967). The area harvested, production techniques and intensity, management options, and product prices have all changed significantly, though, making the loss data obsolete.

Estimates of nearly 30 years later, Oerke*et al.* (1994) updated estimates of real losses in crop output worldwide for the years 1988–1990 on a regional basis for 17 regions. Harvests of food crops nearly doubled as a result of increased agricultural pesticide use, rising from 42% of the global theoretical yield in 1965 to 70% of the theoretical yield by 1990. Unfortunately, 30% of the potential crop was still being lost because efficient pest-management techniques were not and still are not used consistently around the world. 70% of crop output may have been lost to pests in the absence of insecticides (Oerke, 2005).

In light of the ongoing advancements in crop production technology, particularly in the area of crop protection, the loss data for eight major food and cash crops-wheat, rice, maize, barley, potatoes, soybeans, sugar beet, and cottonhave been updated for the period 1996–98 on a regional basis for 17 regions (Oerke and Dehne 2004). Worldwide, pests can result in crop losses of less than 50% (for barley) to more than 80% (for cotton and sugar beet). Actual losses were estimated to be between 26 and 30 percent for sugar beet, barley, soybean, wheat, and cotton, and 35, 39, and 40 percent for maize, potatoes, and rice, respectively (Oerke and Dehne 2004).

Production systems and, in particular, crop protection techniques have undergone substantial change since the early 1990s. This is particularly true for commodities like maize, soybeans, and cotton, where the introduction of transgenic varieties has altered pest management tactics in certain important production areas. The Crop Protection Compendium, published by Commonwealth Agricultural Bureaux International, which covers six important food and cash crops on a regional basis for the years 2001–2003, contains the most recent update to the loss statistics for these crops. cotton, soybeans, potatoes, rice, corn, and wheat (CABI's Crop Protection Compendium 2005; Oerke, 2005). Based on the conditions of production and the level of agricultural production, nineteen regions were identified. The overall potential worldwide loss from bugs ranged from roughly 50% in wheat output to over 80% in cotton production. The anticipated losses for soybean, wheat, and cotton are 26-29%, while for maize, rice, and potatoes, they are 31%, 37%, and 40%.

Global estimates of pest losses in 1996–1998 and 2001–2003 deviate considerably from earlier estimates (Cramer,1967; Oerke*et al.* 1994). New information has taken the place of outdated material from previous publications. Differences can also be attributed to changes in the proportion of locations with varying loss rates in global production. Furthermore, since the late 1980s, crop protection has become more intensive and effective, particularly in Asia and Latin America, where pesticide use has risen above the global average (Yudelman*et al.* 1998).

2. Estimatesofpesticide-relatedproductivity

Higher agricultural losses due to pests must be mitigated by enhanced crop protection, using any combination of biological, mechanical, chemical, integrated pest management, and farmer education. Since the early 1960s, the average yield of the three main crops used to provide human nutrition- wheat, rice, and maizehas more than doubled, and this has coincided with a sharp rise in the use of pesticides. Food prices would skyrocket and food productivity would decline in the absence of pesticides. Farmers would be less competitive on the international markets for main commodities if production were to decline and prices were to rise.

Crop protection in low-productivity environments is mainly restricted to weed control, and actual crop losses to pests can exceed 50% of the potential yield (Oerke, 2005). Significant progress has been made in the education of farmers in many regions of Asia and Latin America, whereas Sub-Saharan Africa remains impoverished and the situation in the former Soviet Union has gotten worse due to a lack of resources (McKeggall, 2010).

Pesticide use patterns differ depending on crop type, climate, location, and user requirements. Plant disease can have a catastrophic effect on crop yields, as the horrific Irish potato famine of 1845–1847 demonstrated. The field of plant pathology developed as a result of this catastrophe (Agrios, 1988). Since the development of synthetic pesticides following World War II, there have been significant gains in agricultural production that have been matched by advancements in efficiency, meaning that fewer farmers on fewer farms are able to produce more food for a greater number of people. The use of pesticides has played a significant role, either directly or indirectly, in the shifting patterns of productivity.

The rate at which pesticides are used has increased in tandem with crop loss and the need to ensure the food's safety and quality. The yearly global market for chemical pesticides is estimated to be 3 million tons, with expenditures of approximately USD 40 billion (Popp, 2011). Entomologists have dubbed the increasing reliance on chemical pesticides the "pesticide treadmill" (Bosch, 1978). Two reactions to pesticide resistance play a significant role in the "pesticide treadmill." The first is to use a less effective pesticide more frequently and at greater doses; this usually leads to increased insect resistance as well as harm to the environment and natural ecosystems. The development and marketing of a novel pesticide is the second course of action.Even after accounting for the considerable shift in agricultural patterns of developing nations due to the growth of the fruits and vegetable sector, the treadmill concept for the years 1965–2000 did not provide a compelling argument for a significant rise in pesticide use (FAO 2000).

Three broad approaches have been used to assess pesticide productivity: econometric models, budget and market model combinations, and partial-budget models based on agronomic projections. Benefit analyses used partial budgeting for a very long period. This approach is used in the most often referenced research on pesticide productivity, including those by Pimentel and several coauthors (Pimentel *et al.* 1978, 1991, 1992). This also applies to Cramer's (1967) assessment of worldwide crop losses and Knutson (1993) assessment. These studies evaluate pest-induced losses on a crop-by-crop basis with current pesticide use, without pesticides, and with a 50% reduction in pesticide use using data from field experiments and expert opinion. For every crop, they create multiple production scenarios in order to evaluate input usage variations.

Then, changes in yield losses and production costs per acre are valued using current prices and summed to get an estimate of the costs associated with changing pesticide use. According to Pimentel *et al.* (1991), one of these studies, overall crop losses increased from 33% in 1974 to 37% of total output in 1986. By contrast, Cramer (1967) calculated that crop losses in North and Central America as a whole were approximately 28% as a result of pests. Crop loss estimates of 37% are arguably exaggerated. In comparison to crop pricing and overall production expenses, pesticide costs are quite cheap. Crop losses comparable to those calculated by Pimentel *et al.* (1991) need to be high enough to justify the use of chemical pesticides at much greater ratesthanobservedtoday.

These types of partial-budget models typically overestimate the productivity of pesticides and, as a result, the financial effects of adjustments to pesticide use (Lichtenberg *et al.* 1988). The models do not account for even short-term farm-level replacement opportunities caused by differences in land quality, people resources, and other features of farming operations.

Field experiments can purposefully ignore substitute options while maintaining all other production procedures constant, with the exception of pesticide use. Additionally, they are frequently carried out in regions experiencing higher than usual pest pressure, which suggests that pesticide yield is likely higher there (Pimentel *et al.* 1991). Because of this, research on pest-related crop losses that use partial-budget models typically overstate crop losses in the agricultural sector.

Other research have combined partial-budget models with output market models in an effort to assess the pesticide-related effects of significant decreases in pesticide use (Zilberman *et al.* 1991; Ball *et al.* 1997). These studies estimate the yield and cost implications of changing pesticide use using the same methodology as partial-budget models.

Models of agricultural commodity markets are then used to estimate changes in output prices and consumption in market equilibrium, based on projected changes in per-hectare costs and yields. These kinds of models have certain substitution options, but not all of them. Within the agricultural sector, replacement opportunities play a major role in determining the productivity of pesticides and, thus, the consequences of reducing pesticide use (Zilberman *et al.*, 1991). When there are many of options for substitution, pesticide productivity generally tends to be low. The actual cost of energy and durable goods has decreased in comparison to the cost of agricultural chemicals (Ball *et al.*, 1997).

However, the cost of hired and independent labor has been rising consistently, both in real terms and in relation to the cost of agricultural chemicals. This indicates that the use of pesticides has grown less appealing in comparison to labor-intensive pest management approaches. These predictions, however, did not account for the potential for the development of new technologies or the deployment of alternative pest-control methods in the absence of chemical control. Additionally, using pesticides can enhance the quality of food while it is being stored and benefit consumers in various ways. According to Zilberman *et al.* (1991), there is a 3-6 USD gain in gross agricultural production for every dollar spent on pesticides. The majority of the gain is transferred to customers as cheaper food costs.

Using econometric models, pesticide productivity can be directly estimated. Models that relate output to input utilization can have their parameters estimated using statistical techniques. The parameters of these models implicitly provide a variety of substitute options. Rates of substitution between inputs can be made to vary in response to variations in input consumption by specifying models with nonlinear input use. Factor productivity and productivity growth in the agricultural sector are frequently estimated using econometric models (Griliches 1963, Ball 1985; Capalbo and Antle 1988, Chavas and Cox 1988, Fernandez-Cornejo *et al.* 1998; Chambers and Pope, 1994). All types of substitution in production, including both short- and long-term alternatives to pesticides on individual farms as well as those operating at the regional and national levels, are captured by econometric models. According to Headley (1968), suchamodelbyusingstate-levelcross-sectionaldata in theUS for the year1963. He determined that an additional dollar spent on pesticides increased the value of output by approximately USD 4, indicating a high level of productivity for that time period. He measured input use by using crop sales as a proxy for output and expenditures on labor, land and buildings, machinery, fertilisers, and other inputs. Headley's estimate of marginal pesticide production may be excessive for a number of reasons. To begin with, because output price and input demand are typically positively associated, using sales as a gauge of output tends to inflate productivity estimates. Second,

According to Headley's criteria, pesticides constitute a necessary inputthat is, production cannot occur without them. Lastly, Headley's specification causes pesticide production to fall more slowly than it should, which results in estimates of pesticide productivity that are once again skewed upward (Lichtenberg and Zilberman 1986). The Headley model produces estimates of the additional amount (value) of output produced by applying an additional unit of pesticides, or the marginal productivity associated with pesticide use. Thus, the total value produced by pesticides is understated when multiplying the marginal productivity of pesticides by the amount of pesticides applied (Pimentel *et al*., 1992).

Using state-level cross-sectional data on sales and input expenditures in the United States, Carrasco-Tauber and Moffitt (1992) used this approach to data similar to those used by Headley (1968). Their implicit estimate of total US crop losses in 1987, at average pesticide use, was 7.3% based on sales as the dependent variable, significantly lower than estimates from earlier studies (Pimentel *et al.* 1991; Oerke*et al.* 1994). According to that criterion, their estimate of pesticide productivity ought to be skewed upward. A dual version of this model was created by Chambers and Lichten-berg (1994) on the presumptions of profit maximization and separability between normal and damage-control inputs.Using this dual formulation, they were able to define production relationships under two different damage abatement standards, none of which required the use of pesticides as necessary inputs. According to those models, implicit crop losses in 1987 ranged from 9% to 11%, which is only roughly a quarter to a third of the amount reported by other researchers (Pimentel *et al.* 1991; Oerke*et al.* 1994). Farm revenue would drop by 6% assuming no change in crop prices, which is far less than what prior research (Pimentel *et al.* 1991; Oerke*et al.* 1994) had predicted. Crop losses without the application of pesticides were estimated to be between 17% and 20%.

3 Costsandbenefits of pesticideuse

The absence of pesticide use data and economic models for non-agricultural pesticides and minor crops makes it difficult to do economic studies of the advantages of pesticides. The evaluation of environmental policies and resource management is increasingly done using cost-benefit analysis. This method monetizes all expenses and benefits by measuring them in currencies, but data limits and challenges in monetizing hazards to human and environmental health may prevent it from being fully implemented. The numerous government initiatives that subsidize pesticide userssuch as price subsidies and deficiency paymentsfurther complicate the economic effects.

The most generally recognized economic incentives are based on the "polluter pays" paradigm, which applies taxes, user fees, and licensing costs. The three countries that have imposed these taxesDenmark, Sweden, and Norwayhave found that their experiences have led to a drop in the use of pesticides. However, their low price elasticity estimates imply relatively little influence in terms of quantity reductions, unless they are set at exceptionally high rates relative to price. There are indications that a more successful approach would have been to recycle revenue and use it for research and information. It would seem more reasonable to use the money made from sales to fund more research or advocate for changes to farming methods (Pearce and Koundouri, 2003).

The toxicity of pesticides varies depending on how they are made and how the receiving environment is set up. Expressing the tax as an absolute amount per unit of toxicity-weighted chemical is the theoretical approach in this case. Unfortunately, there aren't many instances of real taxes being distinguished based on toxicity (the 1999 revisions in Norway being one example). A toxicity-differentiated tax may be effective if substitution between pesticides occurs in a way that reduces the overall toxic impact of pesticides, even while the tax does not considerably reduce the total demand for pesticides. The implication is that a pesticide tax may "decouple" pesticide use from toxicity. The issue with research on pesticide taxes is that not many of them model the "cross-price effects" of such a policy; that is, they do not carefully examine substitution between different pesticide kinds or between pesticides and other inputs like land and fertilizers. The price elasticity of demand for pesticides was constantly low, never exceeding 0.39, according to simulations of toxicity-weighted taxes for the UK. Nonetheless, there was evidence that farmers might transfer between pesticide kinds because the cross-price elasticities between the "banded" pesticides (grouped based on toxicity) were higher than the "own" price elasticities (Pearce and Koundouri, 2003).

However, internalizing the social costs of pesticide usage can be accomplished by the use of the "polluter pays" principle, which involves adding the expenses associated with environmental damage and public health to the price that customers pay. Better (sustainable) pest management can be supported using the money raised from fees and taxes. It could be required to compute the adverse effects of pesticides in order to determine the appropriate level of levies and taxes. Numerous efforts have been undertaken to ascertain the expenses associated with harm to beneficial species, the environment, and public health (risks to customers, farm workers, and drift risk) (Pimentel *et al.* 1992, Pimentel and Greiner, 1997, Pimentel, 2005).

However, the use of pesticides can have a variety of positive societal effects, such as enhanced income and decreased risk, as well as the capacity to recruit workers and create job opportunities. Additional results included the development of increasingly sophisticated community infrastructure, like shops and schools, as well as better health (Bennett *et al.* 2010).

When considering crop pricing and overall production costs, the costs of both chemical and non-chemical pest control approaches are minimal. In the EU, pesticides make up between 7 and 8% of all agriculture production expenses. The percentages vary greatly throughout Member States, nevertheless, ranging from 4% in Slovenia to 11% in France and Ireland (Popp, 2011). In terms of money, 5–6% of all farm inputs in the USA are pesticides (USDA, 2010).

In general, farmers use pesticides on crop land for good economic reasons. The annual cost of the 3 million tonnes that make up the worldwide chemical pesticide market is around USD 40 billion. The worth of the entire crop-protection industry is estimated to be around USD 55 billion due to the growing use of genetically modified herbicide-tolerant and insect-resistant crop seed and sales of agrochemicals used in non-crop circumstances (gardening, home use, golf courses, etc.). The market for traditional agrochemical goods has been directly impacted by the growing sales of genetically modified seeds (McDougall 2010). Despite annual investments of around USD 40 billion globally, pests are thought to inflict an actual loss of approximately 35% (Oerke 2005). The value of thiscrop loss is estimated to be USD 2000 billion per year, yetthere is still about USD 5 return per dollar invested inpesticidecontrol(Pimentel, 2009).

National pesticide benefit studies conducted in the United States indicate that USD 9.2 billion is spent annually on pesticides and crop treatment (Gianessi and Reigner, 2005; Gianessi and Reigner, 2006; Gianessi, 2009). Approximately USD 60 billion in crops that would have been lost to pest devastation are saved thanks to this pesticide application. For every dollar growers spent on pesticides and their use, it shows a net return of USD 6.5. However, the external expenses related to the application of pesticides in crops are not included in the USD 60 billion saved.

When used properly, pesticides can have a major positive socioeconomic and environmental impact by providing safe, affordable, and healthful food. They can also help ensure farm incomes and promote sustainable farm management by increasing the efficiency with which natural resources like soil, water, and land use are used. It goes without saying that improper use of pesticides can have negative effects on the environment and society, and it is important to draw attention to the financial harm that can arise from extensive pesticide use.

When evaluating the net returns of pesticide usage, various trade-offs affecting environmental quality and public health must be taken into account due to the expenses associated with other uses. Pesticides indirectly cost the United States USD 8.1 billion annually, according to Pimentel et al. (1992). This figure includes losses from pest resistance rising; the extinction of pest predators and natural pollinators like bees and butterflies; damage to crops, fish, and birds; contaminating groundwater; and harm to livestock, pets, and the general public's health. According to a follow-up study, Pimentel (2005) calculated that the entire indirect costs of pesticide use in 2005 were around USD 9.6 billion. If the entire cost of social, public health, and environmental issues had been accounted for, the overall cost might have reached USD 9.6 billion (Pimentel, 2005). This indicates that previous evaluations of the environmental and social impact have been too limited. If evaluations were expanded to USD 20 billion annually, the previously estimated USD 60 billion in production benefits to the U.S. from pesticide use would be significantly reduced to USD 40 billion when net effects are taken into account. Even still, the net benefit indicates that pesticides are highly profitable, with a net return of USD 3 for every dollar spent on them (Popp, 2011).

"New generation" pest-management technologies are organisms that have undergone genetic engineering to decrease pest pressure. Through a combination of their innate technological advancements and their role in facilitating and evolving more economical and ecologically friendly farming techniques, biotechnology has produced economic and environmental improvements. This shift in the production system has helped farmers even more economically and has had a significant positive environmental impact, notably lowering GHG emissions. The Environmental Impact Quotient (EIQ), which is based on important toxicity and environmental exposure data pertaining to specific products, aggregates the many environmental and health effects of individual pesticides in various GM and conventional production systems into a single "field value per hectare."TheenvironmentalimpactassociatedwithherbicideandinsecticideuseonGMcrops,as measured

The EIQ indicator decreased by 16.3%. An estimated 356 million kilograms of active ingredient were reduced in pesticides between 1996 and 2008, representing an 8.4% reduction in pesticide use (Brookes and Barfoot, 2010).

Pesticides work well to suppress weeds, illnesses, and a variety of insects. Pesticides must, however, be directed towards the desired crop or animal in order to be effective. One of the main worries about pesticides spreading to non-target organisms is spray drift. Due to evaporation and drift, off-target losses can account for 50% to 70% of the pesticide applied (Pimentel, 2005). The most drift comes from applications in the air, and the least from those on the ground. There are numerous approaches to lessen drift. One way to alter the spray drop size is to include chemicals in the spray that produce more large droplets and fewer little ones (Hall and Fox, 1997). Using new nozzles that are made to produce less tiny droplets while spraying is an additional way to reduce the quantity of fine droplets. The nozzles increase droplet size by lowering the liquid's velocity immediately prior to discharge (Ozkan, 1997).

4. Biopesticidesandintegratedpestmanagement

Biopesticides are becoming more and more viable due to the pressing demand for biological control. Comparing biopesticides to conventional pesticides reveals significant social benefits. However, biological control-which takes the form of augmentative releases—has found a position in the agricultural business, which is still dominated by pesticides. This is especially true for managing pests that are challenging to eradicate with insecticides. Since plants, plant-feeding organisms, and their natural enemies are involved in pest problems in agriculture, national plant quarantine services have often been in charge of regulating biological control agents. Because of this, regulations aimed to prevent introduced natural enemies from becoming agricultural pests over a number of decades (Waage, 1997).

The chemical pesticide concept has been used to biopesticides since there has been a strong inclination to view them as "chemical clones" as opposed to biological control agents. However, biopesticides require control because their "natural" status does not imply that they are safe. Biopesticides are becoming more popular, nevertheless, as a result of the difficulty posed by new, stricter chemical pesticide restrictions and the growing need for agricultural goods with favorable environmental and safety characteristics. Biopesticides take an average of 3 to 6 years and USD 15–20 million to develop and register, compared to 10 years and USD 200 million for synthetic pesticides (REBECA 2007). Many of the top pesticide manufacturers are venturing into the biopesticide sector. The demand for suppliers to employ "sustainable" farming methods by large food purchasers like Sysco, WalMart, and McDonald's has contributed to the increased awareness of biopesticides.

The expected global sales of biopesticides are just USD 1 billion, a negligible amount when compared to the USD 40 billion global pesticide business. It is estimated to account for 2% of the world market for crop protection (Popp 2011). Although the industry is primarily made up of small- to medium-sized businesses, even though biopesticides might be safer than conventional pesticides, It is difficult for one business to completely and adequately finance field research, R&D, and marketing services—all essential components of a thriving biopesticide enterprise. Another challenge is the lack of innovative biopesticide products that are approved and released onto the market (Farm Chemical Internationals 2010).

The use of environmentally based integrated pest management (IPM) by large agrochemical companies is growing. For instance, the Syngenta stewardship team developed the initiative MARGINS—Managing Agricultural Runoff into Surface Water—from a thought leadership proposal. In addition to being necessary for mitigating some of the dangers connected to pesticide use, field margins can serve a number of significant functions. In addition to providing controlled access in the countryside while protecting the cultivated area, they can act as windbreaks to shield crops and soil, affect the flow of water and nutrients through the landscape, and improve the aesthetic appeal of the countryside with flower strips that attract pollinating insects and feed them pollen. Furthermore, field margins can be deliberately maintained to increase the number of game birds by offering food and nesting cover, as well as by serving as refuges or overwintering habitat for a variety of insects, some of which are good predators. Since crop productivity depends on the preservation of limited soil resources, the primary goal of the MARGINS project is to show how crop productivity requirements can be integrated with the needs for biodiversity, water conservation, and soil health. The project was started in 2009 as a start-up pilot project close to Hungary's Lake Balaton, the largest lake in Central Europe. Famed for its natural beauty and abundant wildlife, the lake is surrounded by steep rolling hills of extremely productive loam soils that are prone to accelerated runoff. Conservation tillage resulted inthe lowest pesticide levels in runoff; it doubled when therewasabarebufferstripatthebottomoftheplot.Thebuffer strips are well established with a thick sward of cloverandotherfloweringplants(Syngenta2010).

These outcomes are also in line with the SOWAP (Soil and Water Protection) project that was carried out on these field plots earlier. This EUfunded study showed that conservation tillage systematically decreased runoff, soil erosion, and soil nutrient losses. In addition, microbial biomass activity increased along with the quantities of earthworms, beetles, and other soil fauna. But because profitability was maintained, farmers also benefited. The cost of establishing crops was lowered by 15% to 20%. in conservation tillage. However, crop yields were slightlylower,ascommonlyfoundduringtheconversiontoconservation tillage. Nevertheless, they were higher in dry years,since water availability increased due to reduced runoff fromconservationtillage(Syngenta2010).

This is a promising start-up pilot. Syngenta hopes to expand this experiment throughout Europe to other land use patterns and landscapes, especially in areas where it demonstrates how to apply agri-environment incentives to implement CAP reform. The next big change in agriculture has to come from a constant search for better methods to collaborate with the natural world. A good example of how to satisfy the requirements of sustainable agriculture is MARGINS, which expertly combines cutting-edge technology with reverence for the environment. It is imperative to invest in new technology and conduct further research and development to support a competitive and sustainable agriculture sector that can continue to yield the necessary benefits for the environment, society, and economy. promoting technical advancement, increasing research funding through agriculture policy, and providing instruction to putdevelopments into practice, will help a sustainable, competitivefarmingsectortobalanceproductivitywiththeefficient useofnaturalresourcesanddelivereconomicandenvironmentalpublicgoods(Syngenta,2010).

IPM programs have lowered the cost of pest management and the use of pesticides in fruit, vegetable, and field crops over the previous 20 years. By importing or expanding populations of natural enemies, variety selection, cultural controls, using alternative pesticides, and better timing insect suppression treatments, IPM programs can reduce pest management expenses and pesticide consumption. IPM frequently has the primary advantage for farmers in that it prevents them from using costly pesticides. Nonetheless, a significant portion of the advantages come from the decrease of externalities, which therefore affect other groups. This presents significant measurement and appraisal challenges. The majority of IPM programs still largely dependent on pesticides, despite the fact that they did cut the consumption of pesticides.

However, even in developing nations, there are significant prospects to minimize the effects of climate change on plant health in the future and to further reduce existing yield losses due to new scientific discoveries and technological advancements. Improving the health and standard of living for the impoverished requires a constant search for innovative, affordable, and environmentally responsible ways to combat illness and pest issues. It is now more crucial than ever for low-income countries to adopt an integrated pest management strategy that is more modern and comprehensive. Globally, the institutional environment for IPM has grown increasingly intricate.

In the lack of clear policy frameworks, the tendency toward market liberalization has not always been favorable to IPM. Liberalization of the pesticide industry in the absence of strong restrictions and sufficient market-based incentives may reduce pesticide supply prices, but it may also heighten the likelihood of non-sustainable, wasteful, and ineffective crop protection. The institutional framework and policy of global crop protection must be taken into consideration for an IPM system-wide program to have a meaningful impact (Settle and Garba, 2011). When it comes to IPM, there's a chance that businesses who sell chemical pesticides and biotechnology goods could take advantage of the situation by using IPM as a marketing tool.

However, the European Commission Directive 2009/128/EC on the sustainable use of pesticides establishes a framework for achieving a sustainable use of pesticides. This framework promotes the use of Integrated Pest Management (IPM) and other methods or strategies, such as non-chemical pesticide substitutes, in order to lessen the hazards and effects of pesticide use on human health and the environment. One of the primary elements of the Directive is the requirement for each Member State to develop and implement a National Action Plan that includes activities, timetables, targets, and quantifiable goals. In order to reduce dependency on pesticides and the hazards and consequences they pose to the environment and public health, it also promotes the development and application of integrated pest control and alternative methods or approaches.

Aerial spraying is forbidden (in accordance with regulations), special precautions are taken to protect aquatic environments, public spaces, and conservation areas, and handling, storage, and disposal practices minimize risks to human health and the environment (Official Journal of the European Union 2009). Additional provisions include the need for application equipment to be tested, professional users, distributors, and advisors to receive training and certification.

5. Challengesoftheglobalpesticidemarket

Both on and off farms, pest management is being impacted by globalization. Lower trade barriers boost competitive pressure and provide farmers additional motivation to cut expenses and boost crop production. Liberalization of input markets, which is sometimes referred to as effective market reform, can result in excessive external costs and wasteful use of pesticides (FAO 2009). The unwillingness of the EU to accept genetically modified organisms is one example of how other trade barriers create disincentives for the adoption of new technologies.

It is crucial to note that numerous new businesses in developing nations that manufacture generics are also significant actors in pesticide policy, in addition to the large global corporations. The moving of numerous chemical pesticides off patent is a trend in the agrichemical business. As these substances become into generic insecticides, producers lose their exclusive rights to them. Approximately thirty percent of all sales are made up of generic firms (McDougall 2010). Growing sales of generic pesticides are frequently made possible by lax regulatory oversight and the absence of national policy frameworks focused on integrated pest management, particularly in Latin American and African nations as well as certain Asian nations (FAO 2009).

Approximately thirty percent of pesticides with an estimated yearly market value of USD 900 million that are sold in poor nations do not adhere to internationally recognized quality standards. They pose a major risk to both the environment and human health. In poor nations, these insecticides frequently add to the stockpile of out-of-date pesticides (FAO 2009). Inadequate chemical selection combined with subpar manufacturing and formulation are two potential reasons for low-quality pesticides. Even more low-quality pesticide products are found in developing nations when labeling and package quality are taken into consideration. Years pass without any quality control while falsely stated items continue to reach the market (FAO 2002).

Sub-Saharan Africa, where quality control is typically inadequate is particularly plagued by the issue of low-quality pesticides. The United Nations agencies pushed nations, as well as international and regional organizations, to embrace the globally recognized FAO/WHO pesticide requirements in order to guarantee the production and commerce of high-quality goods. These voluntary norms ought to become legally enforceable in each country. For developing nations without the infrastructure necessary for conducting an accurate evaluation of pesticide products, the FAO/WHO criteria are extremely crucial. The pesticide industry, particularly those that make generic pesticides, should provide FAO/WHO their products for a quality review (FAO/WHO 2010). Loss of export options, particularly for horticultural commodities, as rich countries tighten maximum residue levels is another unfavorable economic effect of increased pesticide use in underdeveloped nations. Agricultural lobbyists in developed countries may take advantage of this circumstance to impose non-tariff trade barriers through environmental norms.

The growing demand for biologically based, sustainable IPM is creating more opportunities for biopesticides. They are "inherently less toxic than conventional pesticides," compatible with other control agents, leave little to no residue, are relatively inexpensive to develop, and support the action of natural enemies in ecologically based integrated pest management (IPM). These are just a few of their advantageous features. They are also frequently very specific. Compared to traditional chemicals, biopesticides are gaining market share at a quicker rate. Large agricultural chemical firms have become highly dynamic in recent years, always searching for new technologies to complement their current offerings or to expand into areas of the market that they are targeting.

Although biopesticides are generally thought of as a substitute for synthetic chemicals, some experts regard them as an addition to the conventional pesticides that are now available on the market. In North America and Western Europe, the use of biopesticides has increased due to growing demand for chemical-free crops and an increase in organic farming (ICIS 2009). A greater total investment in biopesticide research and development, a more well-established IPM application, and a larger area dedicated to organic farming are important factors contributing to this expansion. Products that don't need to be registered and those that are already registered take precedence in these businesses' research and development.

Due to several mergers and acquisitions, the agrochemical industry has experienced a comparatively high level of consolidation. An increasing number of merger and acquisition deals aim to acquire a specific agrochemical product or range in order to bolster the respective product portfolios of the purchasing companies. Although the agrochemical sector has traditionally involved product acquisitions, the amount of these merger and acquisition activities has expanded dramatically during the past ten years (McDougall, 2010).

In 2007, the aggregate expense of research and development for agrochemicals among 14 top corporations amounted to 6.7% of their total sales revenue. It is anticipated that over the next five years, the herbicide industry will grow at the fastest rate, while the insecticide industry is likely to face increased generic pressure and the fungicide industry will develop at a relatively slow rate due to growth in the seed treatment industry. In both developed and emerging markets, the GM agricultural industry is anticipated to keep moving more and more toward multiple trait stacking gene varieties (McDougall, 2010).

Business executives anticipate that developments in genomics will help scientists identify the exact gene locations and sequences that encode important input and output features. The future of plant protection would likely be significantly impacted by a change in research and development funding from input to output qualities. Will the input side innovation cycle continue? Will big agrichemical and life-science companies concentrate mostly on crops with big markets due to the substantial expenditure needed for the development of chemical pesticides and transgenic crops? It's unclear if businesses will create insecticides and input traits for crops with limited uses. These are the principal issues that plant protection research and development are now dealing with.

6. **Conclusions**

The world's food supply is becoming morescarce due to population expansion, increased urbanization and motorization, dietary changes, and climate change. Moreover, more bioenergy and other biobased commodities are produced on agricultural landTo meet the increasing demand for food around the world, a large amount of the output expansion that will be needed will need to come from raising the productivity of the land that is already being farmed. It will be challenging to achieve this, though, as the growth in agricultural productivity worldwide has slowed since the Green Revolution. To reduce future agricultural losses from pests, emphasis needs to be placed on effective crop protection techniques as well as cutting waste across the food chain.

Cost-benefit evaluations are crucial instruments for guiding policy choices pertaining to the application of chemical pesticides. Money is used to quantify the effects of pesticides on the environment, public health, and economy. Measuring the entire range of advantages and disadvantages of pesticide use is fraught with uncertainty, though. One of the most challenging tasks facing policy makers is balancing the dangers and advantages that a community faces by making well-considered trade-offs.

Chemical pesticides will still be used in pest management since products are becoming more environmentally friendly and there aren't always viable alternatives. Producers and consumers alike profit monetarily from pesticide use. Protecting agricultural productivity and quality is one of the main advantages of using pesticides. Large crop losses can be avoided with the help of pesticides, increasing agricultural productivity and farm income.

Use of pesticides has many advantages over hazards. Concerns about the unintended consequences of pesticide residue exposure to humans and the environment persist. By advancing application technologies, pesticide side effects can be minimized. Although they are not anticipated to completely disappear, advancements in plant pesticide delivery systems hold the potential to significantly lessen harmful environmental effects. There are substantial socioeconomic and environmental benefits to using insecticides properly.

The necessity to address the externality issues related to the impacts of pesticides on human and environmental health is one of the arguments for government participation in the management of pest control. Nevertheless, there aren't many incentives for effective and ecologically friendly pest control management techniques. Although some nations have suggested using incentives like taxes and fees for the usage of different chemical categories, the overall demand for pesticides is not greatly decreased. But in the realm of plant protection goods, new guidelines for pesticide safety and information have just been published in a Community framework created by Directive 2009/128/EC.

"New generation" pest-management technologies are organisms that have undergone genetic engineering to decrease pest pressure. Farmers have benefited economically from this shift in the production system, and the environment has greatly benefited as well. However, crops that have undergone genetic engineering and express a control chemical can strongly select for pest resistance. Therefore, the introduction of transgenic crops will even make good resistance-management programs more necessary.

Since many biocontrol treatments are assessed based on how quickly they affect pests, farmers do not view them as acceptable. Instead of focusing solely on short-term yield, as is usually the case with conventional methods, evaluation of the efficacy of biocontrol agents should take long-term effects into account. In comparison to the pesticide market, biopesticide sales are relatively tiny worldwide. Nonetheless, biopesticides' market share is increasing more quickly than that of traditional chemicals. To broaden the range of tools available for pest management, a concentrated effort in both research and policy should be made to improve the competitiveness of chemical pesticide substitutes. However, the availability of substitute pest-management instruments will be essential to meeting production requirements, and fierce competition is anticipated in these specialized sectors.

Modern technologies and new scientific understanding offer developing nations the chance to minimize the effects of climate change on plant health in the future and further reduce existing yield losses. Enhancing the health and standard of living of the impoverished requires a constant search for innovative, economically viable, and environmentally responsible ways to manage pest and disease issues. It is now more important than ever for low-income nations to adopt an integrated pest management strategy that is more modern and comprehensive.

In order to address biological, biochemical, and chemical research that may be applied to ecologically oriented pest control, the total investment in pest management as well as the rate of new discovery should be raised. From a societal standpoint, private sector research is underfunded since businesses only want to maximize what is known as suppliers' surplus. Businesses will compare the projected revenues from their proprietary research products; they will not take user and consumer benefits into account. The public sector should prioritize its research investments on pest management fields that are not being pursued by the business sector. In the past, the public sector was mainly in charge of information transmission, but this has changed as it has become more privatized. In order to guarantee informed decision-making in both the public and commercial sectors, the public sector must fulfill its obligation to deliver high-quality education by placing a strong emphasis on systems-based multidisciplinary research.

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