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Transitioning To Organic Agroecological Pest Management Is Critical For a Sustainable Agricultural Future

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ABSTRACT: To ensure yields and reduce environmental impact, agricultural sustainability must be improved. It is generally acknowledged that environmental change has both negative and positive effects. Investing in traditional Agriculture has been able to maintain its current production advantage. Organic farming, on the other hand, usesAgroecological management has a limited potential for long-term output and growth. In the future, yields will be higher. To solve problems, traditional systems have relied on reductionist methods. Pests, mainly by using pesticides to remove biological factors that decrease output. However, they come at a cost to human and environmental health, as well as putting agricultural systems at risk. Pest resistance to these drugs or characteristics is on the rise. Alternatives are required, and they must be found.are found in organic farming methods. Despite the fact that organic and agro ecology methods are both viable options, this feature is more than pest control; it is a critical component of our agricultural future. Increased investment and the use of new analytical methods to enhance plant performance breeding for and managing these systems will result in higher yields and robustness than current methods. Component-by-component analysis

KEYWORDS: Agro Ecology, Biodiversity, Organic Agriculture, Plant Breeding, Sustainability.

1. INTRODUCTION

Agricultural experts agree that as the world's population grows, so will the quantity of food and fiber consumed, despite less resources available for production .This, however, cannot be isolated from the global need to transition to more sustainable agriculture, particularly in terms of pest control techniques . Meeting food and fiber production requirements in an economically feasible way while enhancing environmental health and individual and social well-being are key elements of sustainable agriculture systems .Pest control operations have a significant impact on all of these principles of sustainable agriculture. The debate over whether conventional or organic agriculture is the best path forward is raging, with many experts debating the efficiency tradeoffs between organic and conventional agricultural methods. We believe that when enough money is invested in creating comprehensive organic alternatives, these compromises become less significant. Given the complexity of our food production systems, we must approach long-term objectives for sustainable agriculture in the context of the whole system, rather than focusing on individual breakthroughs[1].

Organic agriculture is a production style that is ideally equipped and motivated to take the lead in pest control research and development. Sustainability 2018, 10, 2023, 2 of 25 "principles of health, ecology, justice, and caring" Organic certification and product identification are provided by the organic label for around 1% of total agricultural area under organic management globally , and this branding enables economic advantage to organic farmers by allowing customer choice. Although organic farming methods are diverse, there is a lot of common ground across growing enterprises when it comes to pest control best practices. Agro ecology, a related movement,

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focuses on the study of essential components of sustainable production systems, which organic agriculture relies on . While not perfectly aligned (for example, organic farming restricts synthetic and transgenic inputs, whereas agro ecology seeks to create resilient polyculture; although, organic farming and agro ecology are more blended in some countries)[2] , we believe that the nexus of these approaches is the future agricultural system, and we will refer to their common ground as “organic agr” throughout. In conventional and organic agriculture systems, there are two responses to pest challenges: Weed, disease, and insect pest control is a significant problem in all agricultural systems. Weeds cause a 34 percent decrease in yields, while plant diseases and animal (mostly insect) pests cause 16 percent and 18 percent reductions in yields, respectively. Overall, pre-harvest pests are thought to reduce crop yields by approximately 35%. Pest problems fluctuate with the seasons, and it's impossible to anticipate how this variance may move in the face of climate change, although warming has pushed pest ranges from the equator to the poles . In response to these dynamic demands, resilient mechanisms are required for food security. While insect problems affect all agricultural operations and will continue to do so, organic and conventional techniques take distinct tactics to mitigating pest damage.

Pest control in traditional systems is mostly accomplished via the purchase and use of synthetic pesticides. Pesticides cost about $40 billion USD globally, with nearly 2 million metric tons of active ingredient used . In the United States alone, more than $12 billion USD is spent on more than 200,000 metric tons of active chemicals, with the majority (>80%) being used in maize, soybean, cotton, potato, and wheat crops, and herbicides accounting for 76% of total pesticide use [20]. Despite the fact that there aren't exact figures for pesticide application on every horticulture crop, pesticides are widely used. [3]According to the most current comprehensive US statistics, more than 50% of planted acreage of each vegetable crop and bearing acreage of each fruit crop is treated with at least one pesticide in the majority of crops examined. In total, over 25,000 metric tons of fungicides, 5000 metric tons of herbicides, and 5000 metric tons of insecticides are applied to horticultural crops in the United States each year , with tomatoes (Solanum lyocpersicum), grapes (Vitus spp.), and apples (Malus x domestica) being the largest single users . Indirect costs from poor human or ecological health effects owing to pesticide usage are estimated to reach $8 billion USD per year in the United States, however others caution that these figures may be low and old. To combat insect issues, traditional agriculture has depended on bought off-farm input.

This strategy has enabled investment, R&D, and increased agricultural output, but it is incompatible with long-term sustainability objectives. Non-occupational pesticide exposure poses a danger as well. Children of agricultural laborers, for example, are more likely to be exposed to pesticides in their family setting .Prenatal pesticide exposure is linked to an elevated incidence of some pediatric malignancies as well as neurodevelopment consequences[4] . Pesticide residue is present on food items, however the Environmental Protection Agency (EPA) in the United States limits permissible residue levels to a “reasonable assurance of no harm,” as required by the Food Quality Protection Act of 1996 .More than half of residue may be removed by washing vegetables as directed. Despite this, metabolites from pesticide residue ingestion have been found in the general population of the United States .Organic food is preferred by consumers because of claimed health advantages, such as decreased pesticide residue exposure when compared to conventional produce.

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Organic produce contains fewer pesticide residues than conventional produce, and people who ate organic diets had fewer detectable pesticide metabolites in their urine . However, the clinical effects of reducing pesticide residues that are already below EPA-regulated levels are unknown .Importantly, at least one research backs organic farming as a safer option for farmers: Organic farmers exhibited fewer unfavorable health indicators, such as chromosomal abnormalities, than conventional growers who used pesticides, according to a research in Portugal. The ban of synthetic pesticides on organic farms, as well as the use of safer alternatives such biopesticides, biologically derived chemicals, when required, may be linked to reduced pesticide exposure for farmers and consumers of organic food . Microbial-based products, such as Trichoderma spp., may outcompete or antagonize plant-pathogenic fungus while posing no known health hazards to all non-target species, including humans. (i.e., Trichoderma harzianum T-22 strain. This is not to imply that insecticidal or antimicrobial chemicals (such as spinosad, pyrethrin, and copper products) do not exist in organic agriculture; nevertheless, control methods cannot depend only on these products. While safer crop-targeted controls are valuable tools for organic farmers, this does not mean that organic management is just an input replacement for conventional pesticides, nor that organic agro ecological methods prioritize the use of these products above the use of preventative measures[5]

2. DISCUSSION

a. *Application:*

From the application of the pesticide through the eating of the generated food, pesticide usage presents a threat to human health. Agricultural workers and pesticide applicators, in general, suffer the most serious health hazards as a result of near and frequent chemical exposures, particularly with concentrated pesticide products. Among the United States, physician-diagnosed pesticide poisonings in agricultural laborers may be as high as 20,000 per year. Acute or chronic impacts on health may result from acute or chronic exposure. While long-term consequences are difficult to assess, there are links between chronic pesticide exposure and the prevalence of certain cancers in adults[6].Other long-term effects on endocrine, reproductive, and neurological health are also being researched . Occupational exposure risks to agricultural workers, particularly immigrant populations, are frequently discussed as part of a larger debate of environmental and social justice concerns. On-occupational pesticide exposure poses a danger as well. Children of agricultural laborers, for example, are more likely to be exposed to pesticides in their family setting.

Prenatal pesticide exposure is linked to an elevated incidence of some pediatric malignancies as well as neurodevelopment consequences. Pesticide residue is present on food items, however the Environmental Protection Agency (EPA) in the United States limits permissible residue levels to a “reasonable assurance of no harm,” as required by the Food Quality Protection Act of 1996 .More than half of residue may be removed by washing vegetables as directed. Despite this, metabolites from pesticide residue ingestion have been found in the general population of the United States. Organic food is preferred by consumers because of claimed health advantages, such as decreased pesticide residue exposure when compared to conventional produce [7]. Organic produce contains fewer pesticide residues than conventional produce, and people who ate organic diets had fewer detectable pesticide metabolites in their urine. However, the clinical effects of reducing pesticide residues that are already below EPA-regulated levels are unknown .Importantly, at least one research backs organic farming as a safer option for farmers: Organic

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Microbial-based products, such as Trichoderma spp., may outcompete or antagonize plant-pathogenic fungus while posing no known health hazards to all non-target species, including humans. (i.e., Trichoderma harzianum T-22 strain. This is not to imply that insecticidal or antimicrobial chemicals (such as spinosad, pyrethrin, and copper products) do not exist in organic agriculture; nevertheless, control methods cannot depend only on these products While safer crop-targeted controls are valuable tools for organic farmers, this does not mean that organic management is neither just an input replacement for conventional pesticides, nor that organic agro ecological methods prioritize the use of these products above the use of preventative measures. Instead, it shows that there is ongoing, motivated research in organic systems for lower-toxicity pest control methods that may be integrated as part of agro ecological growing operations. Pesticides may potentially destabilize ecosystems by having unintended consequences on other species. Pesticide usage has been found to reduce insect populations to a small number of species Pesticide usage has been linked to population decreases of pollinators, natural enemies of pests such as predators and parasitoids , and sub-lethal impacts on these insects. On farms, insects aren't the only ones that suffer: fungicide usage decreases the functional diversity of rhizosphere-associated microbial communities[8].

The value of ecosystem services provided by wild insects alone (excluding honey bee colonies) in the United States exceeds $57 billion USD. There is a recognized agricultural economic incentive to preserve these insect species that offer ecosystem services like pollination or pest predation. It was suggested in one small grain research that insect predators lost to pesticide spray may have kept pest populations in control, saving (at the very least) the expense of treatment. Soil microorganisms offer ecological services that have yet to be quantified in terms of economic losses.Sustainability 10th of October, 2023 8 out of 25Furthermore, pesticide impacts are not limited to agriculture; a wide loss of insect species variety and abundance has an ecological (and economic) cost. Significant reductions in the number of flying insects have lately been observed, which may be due in part to pesticide usage. Even when pesticide concentrations are at or below permitted levels, pesticide run-off into rivers decreases stream invertebrate biodiversity. In addition, increasing fungicide and pesticide usage was linked to a decrease in bird species diversity .The usage of neonicotinoids in pollinator-dependent crops, such as cucurbit crops, is an illustration of the ecological consequences of certain conventional chemistries.

Pumpkins, summer and winter squashes (Cucurbita spp.) are among the Cucurbita spp. crops, and insect pests such as Acalymma vittatum (striped cucumber beetles) are frequently managed by systemic neonicotinoid treatments. Despite the fact that many species of bees visit squash blossoms, systemically applied neonicotinoids have been found to transfer into nectar and pollen at physiologically active levels for bees. Sublethal neonicotinoids dosages have been shown to have detrimental impacts on characteristics including foraging behavior and growth rates in generalist visitors like honeybees and bumblebees. Overall, the use of neonicotinoids for insect

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pest management in cucurbit crops is an example of how a broad-spectrum pesticide may have real-world consequences for other insects that farmers rely on for crop success.

Organic farmers, on the other hand, can handle pests like A. vittatum while minimizing off-target impacts by using a variety of cultural management techniques. Growers may physically protect crops on a limited scale, or if outbreaks are seasonably predictable, the planting date can be changed to avoid co-occurrence of susceptible plants and the pest. More significantly, there are scalable and environmentally sound management strategies. Planting cucurbit crops in a polyculture, for example, has been found to decrease insect damage. Perimeter trap cropping, which involves growing extremely attractive plants around the field's edge to lure pests away from the marketable crop, is a kind of polyculture that has been proven to be successful in pest control. Using non-preferred cucurbit cultivars may also decrease insect damage and is beneficial at a farm size. Finally, natural enemies might be given a home, and parasitoids' function could be better understood and encouraged. The use of cultural practices to replace neonicotinoid pesticides in conventional systems is an example of a long-term solution with less off-target impacts that organic agro ecological pest control methods may offer[9].

b. *Advantage:*

Pesticide use to ensure yields presents significant hazards to farmers and food security: pesticide application costs are often underreported, and pesticide effectiveness is fickle over time. Since 1960, direct pesticide expenditures in the United States have increased fivefold in inflation-adjusted terms, while the relative price of pesticides compared to labor or fuel has decreased, reducing incentives to reduce pesticide usage. Health and environmental costs are incurred that are seldom included into any price differential but are paid by the general population , and more recent studies estimate indirect costs to be in excess of $8 billion USD . The lower sticker price of conventionally produced crops may seem to be a critique of organic production techniques' efficiency on the surface, but the complete accounting shows a significant hidden cost to both farmers and our food system as a whole. Furthermore, the strong selective forces exerted by pesticides on pests to overcome control measures can put conventional systems on a precarious “pesticide treadmill,” in which pest resistance develops as pesticides are deployed, necessitating dose or frequency increases or replacement with new pesticides or pesticide mixtures.

Since 1920, more than 586 species have developed resistance to at least one pesticide, with the number of occurrences of resistance for a specific insect-insecticide combination exceeding 10,000 across all cropping systems. Since 1960 and 1970, there have been over 300 instances of weeds and fungus, respectively. In row crop systems, the development of pest resistance to synthetic pesticides and transgenic resistant crops has been observed.In response to damage from the fruit and shoot borer the only commercially available genetically engineered Bt vegetable crop, Bt eggplant , has been deployed on farms in Bangladesh since 2014 , making it difficult to predict how quickly resistance will develop. Overall, farmers are burdened by the loss of pesticide or transgenic effectiveness, which has repercussions across the supply chain. The control of cucurbit downy mildew in cucurbit crops is an example of where dependence on pesticides comes at a high cost and results in recurrent loss of pesticide effectiveness. Cucurbit downy mildew (Pseudoperonospora cubensis) is a disease that affects all commercially produced Cucurbitaceous, including watermelon (Citrullus lanatus), melon (Cucumis melo), squash (Cucurbita spp.), and cucumber (Cucumis sativus).

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Annual outbreaks of cucurbit downy mildew infected the United States in 2004, overcoming resistance to cucumber cultivars and many fungicides, while similar pathogen dynamics were occurring worldwide. The pathogen has acquired resistance to a variety of fungicide chemistries throughout time. There are already effective pesticide regimens that rotate products and spray every 5–7 days to prevent the illness, but they cost $150–$235 USD per acre. Organic farmers did not have this choice; in general, organic agriculture lacks curative chemical controls, and resistant crops are a key component in avoiding significant losses. In response, Cornell University researchers sought to create disease-resistant cucumber genotypes. Following the 2004 epidemic, some of the first reported CDM-resistant slicing cucumber cultivars were released on the market. Utility patents do not limit continuing breeding efforts from this material, which have resulted in an enhanced CDM-resistant slicing cucumber variety and ongoing work to create CDM-resistant pickling cucumber types co-selected in organic and conventional production methods. This case study demonstrates how organic plant breeding may help researchers create pesticide-resistant crop types that potentially eliminate the need for pesticides.

c. Working:

Organic seed is now encouraged by US and worldwide organic standards since organic agro ecological systems benefit from both organically bred and organically produced seed. Through transgenerational defensive priming or induction, seeds produced organically may be better prepared for future pest challenges. Priming refers to a condition in which a plant is able to react to biotic stress more quickly and strongly, while induction refers to defenses that have already been engaged. Although the exact mechanisms of transgenerational induction and priming are unknown, evidence suggests that heritable epigenetic alterations are to blame. Insect and disease damage may be mitigated in either condition, and “plant vaccination” via priming has been promoted as a major IPM method. However, the transgenerational impacts from parent plant (produced at organic seed farm) to offspring seed are the subject of our research (grown at organic production farm).Many instances of trans-generational defensive induction and priming from previous herbivory may be found in the ecological literature. Herbivory on maternal plants has been demonstrated to prepare offspring for future infestations in a broad range of plant species since the foundational article with wild radish (Raphanus raphanistrum), with processes studied in detail using model plants Arabidopsis thaliana and Solanum lycopersicum.

Furthermore, it has been shown that the maternal abiotic environment influences how progeny plants react to pathogen infection biotic stress. In addition to seed transfer, the Guatemalan potato moth (Tecia solanivora) causes overcompensation in potato (Solanum tuberosum), resulting in greater production in the injured plant. It would be fascinating to see whether these overcompensation effects will continue over seasons of clonal growth. Overall, further research into this phenomena may lead to significant breakthroughs for the organic seed business and farmers. Plant breeding for indirect resistance is at the forefront of pest control innovation in organic agro ecological systems. Plant characteristics that assist insect predators by giving a signal about prey position, habitat, or food supplies, or confuse herbivore host discovery are examples of traits that may enhance indirect resistance. While plant breeders may be interested in breeding for favorable plant volatile profiles, the genetic variation for resistant volatile profiles found in wild ancestors and landraces is largely absent in today's elite cultivars , Sustainability 2018, 10, 2023 12 of 25, making introgression of these traits difficult. Plant volatiles' ability to assist or hinder insect pest host discovery is still mostly understood, and organic plant breeders and chemical ecologists should investigate how beneficial they may be in an agricultural context. Agricultural pests continue to show a remarkable capacity to develop resistance to pesticides, particularly conventional pesticides and genetically modified resistance characteristics.

Because it is foreseeable that a pest would overcome any resistance characteristic under strong selection pressure, the organic community should take the lead in establishing effective management methods that reduce pest selecting pressure for long-term resistance via plant breeding. Plant breeders should choose quantitative resistance, which is an imperfect degree of resistance given by many genes rather than qualitative resistance, which is produced by a single gene. Pests are less likely to quickly develop to overcome several small selection pressures at the same time if they are bred for quantitative resistance. This increases the lifetime of plant resistance efficacy. Breeding for quantitative resistance to pathogens and insect pests is complicated by a lack of understanding of molecular mechanisms and difficulties with accurate phenotyping, particularly in discrete components of plant-insect interactions, and the pest population ultimately determines the durability of resistance .Overall, organic plant breeders should prioritize diversified plant breeding efforts to control pests via reduced selection pressure.

3. CONCLUSION

We must invest in agricultural systems that will provide enough yields to feed humankind while reducing environmental damage. Today's high yields from conventional agriculture are inextricably linked to a hidden cost to the environment due to pesticides' negative effects. While organic agriculture's ability to feed the globe is still developing, organic agro ecological methods have the potential to sustainably feed the world's population through pushing pesticide alternative research and development. As agricultural scientists, our duty is not to preserve the status quo, but to follow the route of past generations' discoveries in order to secure the productivity that presently sustains our population.

Agriculture, after all, is a human creation that has been in flux for millennia as new crops were accessible, growing methods were created, pest and environmental problems arose, new areas became available for production, and markets grew. Importantly, since their widespread introduction in the twentieth century, our understanding of the consequences of synthetic agricultural pesticide usage has changed as well. In order to enhance the sustainability of our agricultural output, how will we alter our management techniques Can we go to more sophisticated, multi-faceted methods that are robust and sensitive to live agro ecosystems We may concentrate on the issues we need to address toward the application of organic agro ecological methods in plant breeding and crop management for organic agricultural systems by reframing the yield gap between conventional and organic agriculture as an investment gap[10].

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