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Eco-friendliness of Weed Management Methods in Organic Farming: The Need for Extension Education

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Abstract. Weeds constitute a major problem in crop production, and smallholder farmers have depended on the wide use of conventional weed control methods that mostly involve the use of synthetic chemicals which have attendant adverse effects on man, other organisms and the environment. In the face of the environmental and human hazards posed by the indiscriminate use, abuse and misuse of these chemicals, government at all levels as well as international organisation like the European Union (EU) have advocated eco-friendly weed management methods in order to maintain a healthy and sustainable environment. Research revealed that farmers do not make wide use of the eco-friendly control methods owing to a number of factors such as lack of farmers' acceptability, cost implication, labour intensiveness and lack of virile extension system to mention few. It is therefore imperative to discuss the EU's position on use of synthetic chemical in weed management, non-chemical or eco-friendly weed management methods, benefits associated with the methods and their limitations, dangers associated with the misuse of synthetic chemicals in weed management as well as the role that extension education can play in ensuring wide use of non-chemical methods of weed management and Integrated Weed Management (IWM). Future research needs are also identified.

Keywords: Eco-friendliness, weed management, organic farming, extension education.

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1. Introduction

Weeds constitute a special class of pests which seriously limit the production of the major crops on any scale. They compete with the crops for nutrients, air, light and moisture and they play significant roles in crop loses (Ofor et al*.,* 2009). In a review of crop losses due to pests, it was stated that: 'overall, weeds produced the highest potential loss (34%) with animal pests and plant pathogens being less important causing losses of 18% and 16%' (Oerke, 2005).

Minimizing loses due to weeds, pests and diseases necessitate farmers' choice of synthetic chemical use which is not without adverse effects on the environment and human health. Oruonye & Okrikata (2010) posited that the synthetic agro-chemical methods of crop enemies control have a lot of adverse ecological impact. Herbicides accounted for 46% of global pesticide sales in 2005, with insecticides (26%) and fungicides (23%) accounting for smaller proportions of the $33,600 million total spending (Agrow, 2006). This takes a lot of the farmers' income and hence affects their profit which will in turn influence their livelihood.

The need to maintain a healthy and sustainable environment calls for non-chemical approaches to weed management. While herbicides are considered the main means of weed control in many countries of the world, there is increasing recognition that non-chemical methods of weed control have numerous advantages both for man and his environment (Bond et al., 2003). Non-chemical weed control methods were advocated for the purposes of environmental health, human health, avoidance of weeds resistant to herbicides, and to comply with the new EU regulatory actions requiring farmers to adopt Integrated Weed Management (IWM) (Moss, 2010; Ofuoku et al., 2008).

It is on this note that the paper discusses EU position on chemical use, non-chemical weeds control methods, benefits associated with non-chemical methods, limitation of use by farmers as well as the role that extension education can play in ensuring wide use of non-chemical methods of weed control.

2. New EU regulatory actions

In 2005, EU and member states came up with a strategy involving themes which has two important components: (i) Theme 91/414, which defines active substances permitted for use in the EU and (ii) Regulation 396/2005, which defines the maximum residues levels (MRLs) permitted or allowed in food and feedstuffs in the EU (Rutherford, 2009). This led to the banning of those chemicals that are not EU compliant. The position of EU was as well stressed in 2009. In 2009, EU and the member states came up with another Thematic Strategy to minimise the hazards and risks to human health and the larger environment from the use of synthetic pesticides. The Thematic Strategy consists of four different legislations with varying emphases, which will directly or indirectly, affect pesticide use in all EU countries. These are: (i) Agrochemical Authorization Regulation (EC 1107/2009), which is concerned with the placing of plant protection products on the market, and introduces the concept of hazard assessment for the approval of active substances (ii) Sustainable use of Pesticides Directive (2009/128/ EC) which promotes Integrated Pest Management and encourages non-chemical methods of plant protection in order to reduce dependency on pesticides (iii) Statistics Regulation (EC 1185/2009) which relates to pesticide sales and use statistics and (iv) Machinery Directive Amendment (2009/127/EC) (Moss, 2010; Chemical Regulation Directorate (CRD), 2010). These set standards for new pesticide application regime for sustainable environment and human health. Of these legislations, it is the second that emphasized non-chemical methods or reduced chemical methods of weed control for healthy and eco-friendly environment.

3. Weed management methods in organic farming

An array of weed management methods in organic farming are available and some of these will be discussed in broad categories below.

3.1. Preventive management method

Preventive management method refers to any method that aims to prevent weeds from being established in a cultivated crop. Examples of these methods are: the use of certified weed-free seed; only transporting hay that is weed free; making sure farm equipment is clean before moving from one location to another; and screening irrigation water to prevent weed seeds from traveling along irrigation ditches.

3.2. Manual and mechanical management method

Manual and mechanical techniques such as pulling, cutting, and otherwise damaging plants, may be used to control some weed species, particularly if the population is relatively small (Tu et al., 2001). Although it is labour intensive and may be expensive where cheap communal labour are not available. It is however very eco-friendly and can be used in combination with other weed control approaches. There is a growing volume of scientific literature (Lee et al., 1999; Slaughter et al., 2007) on the automation of weeding of agricultural fields. These novel approach to weed control has been tested on small scale and more research are been carried out to improve the efficiency of this weed management method with the hope that it will soon be applied and widely adopted in commercial agriculture. However, more recent report indicates that some new robotic weeders, Robocrop (www.garford.com) and Robovator (www.visionweeding.com), for intra-row weed control in row crops are now operating on a commercial basis (Melander, 2011). Another physical weed control method worthy of mentioning is solarisation. Soil solarisation is a special mulching technique in which moist soil is covered by polyethylene film and heated by solar radiation for several weeks. It is used for soil thermic disinfestation, accomplished by mulching the soil under a plastic film, which produces a greenhouse effect, so that soil temperature rises to levels which are lethal or injurious to many soil borne organisms, including pathogens, seeds, and weed seedlings (Marenco & Lustosa, 2000). In areas with high levels of solar radiation this method has been successfully used not only for weed control, but also for control of soil borne pathogens.

3.3. Thermal management method

Thermal management method can be divided in two groups according to their mode of action (a) the direct heating methods (flaming/burning, infrared weeders, hot water, steaming, hot air) and (b) indirect heating methods (electrocution, microwaves, laser radiation, ultra violet light), with freezing as a third and opposite plant stress factor (Rask & Kristoffersen, 2007). There is a renewed interest in flame weeding as an alternative to herbicides in Europe (Ascard, 1990, Rasmussen & Ascard, 1995), in the US and Canada (Lague et al., 1992; Knezevic et al., 2012; Shrestha et al., 2012; Loni et al., 2014) and other parts of the world (Ascard, 1995). Flaming/ burning is controversial as to its effectiveness; only seeds present in the windrow and on the immediate soil surface below the windrow are affected by burning. Few if any, of the weed seeds beneath the soil surface are killed by flaming or other radiant heat sources. For soil stewardship and preservation of organic matter, burning should only be practiced on windrowed straw or on gathered weed materials from patches within the field known as spot burning.

3.4. Biological management method

Biological management of weeds involves the deliberate use of host-specific phytophagus arthropods and plant pathogens to reduce the population density of a target species below its economic injury level (Shroeder et al., 1993). Three methods of biological weed control in crops can be distinguished: the inoculative or classical approach; the inundative or microbial approach; and the system management or augmentative approach.

Classic approach involves the release of a relatively small number of control agents; these agents feed on the weed, reproduce and gradually suppress the weed as their population grows; arthropods are generally used as control agents. Successes with inoculative biological weed control has been recorded in control of *Chondrilla juncea* L. (skeleton weed) in wheat *Triticum aestivum* L. (wheat) in Australia (Cullen, 1985; Espiau et al., 1998) and *Zygogramma suturalis* F. (ragweed beetle) to control *Ambrosia artemisiifolia* L. (common ragweed) in Russia, Croatia, China and Australia (Reznik, 1996; Muèller-Schaèrer, et al., 1999). Although much attention has been given to the system management or augmentative approach in scientific literature, it has remained largely a theoretical concept (Muèller-Schaèrer, et al., 1999). There has been great success with the application of inundative biological weed control, and this led to an increase in the availability of weed biocontrol products (Muèller-Schaèrer*,* et al., 1999).

3.5. Cultural management method

Cultural management method refers to any technique that involves maintaining field conditions such as growing competitive crops in the rotation, timely cultivation, mulching, using agronomic practices that promote vigorous crop growth, and growing a competitive variety, all contribute to an effective weed management program (Hutchinson & Eberlein, 2003). These practices can also have additional benefits of enhancing soil fertility and facilitating the management of diseases and pest. The use of mulching for weed control is popular, affordable and widely accepted among smallholder farmers and when used in combination with other weed management practices can ensure a high level of weed control with the added advantage of soil moisture conservation, prevention of nutrient losses through run-off, and also replenishing soil fertility as the mulch slowly decomposes. The ability of some crops to grow quickly, produce extended canopies and out-compete weeds species has also been exploited for weed management in organic production system. In most cases, once the crop are established, they smolders the weeds, thus ensuring good weed control with little or no other human intervention.

4. Integrated Weed Management

A number of non-chemical weeds management practices has evolved as a result of the need to maintain a healthy and eco-friendly environment. These management practices metamorphosed to the popular IPM/IWM. According to CRD (2010), EU defined IPM/IWM as a careful consideration of all available plant protection methods and subsequent integration of appropriate measures that discourage the development of pest/weed populations and keep the use of plant protection products and other forms of intervention to levels that are economically and ecologically justified and reduce or minimise risks to human health and the environment.

The implementation of Integrated Pest Management is obligatory, and low pesticide-input pest management must be promoted (Moss, 2010). IWM is subsumed in IPM which emphasises practices such as cultural, mechanical, biological and minimised or non-use of chemical means of weed control (Swanton and Weise, 1991; Bond et al., 2003). United State Agency for International Development (USAID) (2013) classified IPM practices into two: pre-planting practices and post-planting practices. It stressed that some of the pre-planting practices are proper land preparation, mulching and crop rotation while that of the post planting practices are maintaining proper plant density and spacing, cover cropping, mulching and hand weeding among others.

IWM is a science-based decision-making process that coordinates the use of macro and micro-environment information, weed biology and ecology, and all available technologies to control weeds by the most economical and ecologically viable methods (Rao & Nagamani, 2010). Integrated Weed Management combines various preventative, cultural, genetic, mechanical, biological, and chemical weed control practices into a single program. While no single control measure is likely to provide complete weed control, the systematic implementation of the various components of integrated weed management can make significant contributions to weed control efforts (Knezevic et al., 2012). When properly implemented, IWM can lead to sustainable food production, minimized drudgery, and reduce the cost of removing weeds from crops (Chikoye et al*.,* 2004). The decision making process utilised to arrive at the particular weed management technique should be based on cost factor, its impact on the soil and environment. The weather and climate of the farm location should also be put into consideration when formulating a suitable weed management programme (Tea Research Institute (TRI), 2003).

An integrated weed management approach advocates the use of all available weed control options such as selection of a well-adapted crop variety or hybrid with good early season vigor and appropriate disease and pest resistance, that is plant breeding; appropriate planting patterns and optimal plant density; precise timing, strategic placement, and appropriate quantity of nutrient application; appropriate crop rotation, tillage practices, and cover crops; suitable choice of mechanical, biological, and chemical weed control methods; and alternative weed control tools e.g., flaming, steaming, infrared radiation, and sand blasting (Knezevic *et al.*, 2012).

5. Challenges associated with over-reliance and indiscriminate use of synthetic chemicals for weed control

5.1 Herbicide resistance

Selection for herbicide-resistant weed biotypes is greatly accelerated with the continuous use of herbicides, particularly those with a single mode of action (DiTomaso, 1997). In a survey, Shroeder et al. (1993) reported that from 20 species with highest relative score for abundance and frequency, 11 species have triazine–resistant population in up to 11 countries per species, three are resistant to 2,4-D, three to MCPA, and four to aminotiazole, barban, paraquat, propham, growth regulators and pheny urea. Additionally, widespread resistance to the sulfonylurea herbicides (sulfometuron and chlorsulfuron) has been reported for *Salsola tragus* (Russian thistle) along Califomia highways (Holt and Prather 1996), while in Washington, continuous use of picloram led to selection for resistance in yellow starthistle (Callihan & Schirman, 1991; DiTomaso, 1997).

5.2 Loss of biodiversity

Continuous broadcast use of one herbicide or a combination will often select for plant species demonstrating greatest tolerance. Since even selective herbicides tend to injure several species, repeated use will eventually have a negative impact on plant diversity (DiTomaso, 1997). Agricultural pesticides can reduce the abundance of weeds and insects which are important food sources for many species. Herbicides can change habitats by altering vegetation structure, ultimately leading to population decline, and the more toxic herbicides threaten exposed wildlife (Isenring, 2010). In an ecological study by Relyea (2004), Roundup completely eliminated two species of tadpoles and nearly exterminated a third species, resulting in a 70 per cent decline in the species richness of tadpoles, and an indirect, negative effect on the biomass of insect predators. There are extensive research investigating changes in native plant communities, declining butterfly population and increased frog deformity (Kolpin et al., 1998).

5.3 Ground water contamination

The use of pesticides in agriculture may lead to contamination of surface and ground waters by drift, runoff, drainage and leaching. Surface water contamination may have ecotoxicological effects for aquatic flora and fauna, and for human health if used for public consumption (Cerejeiraa et al., 2001). In a study of some high use herbicide in the US namely: atrazine, cyanazine, simazine, alachlor, acetochlor, metolachlor, Barbas et al., (2001) reported that among different agricultural areas, frequencies of detection of the herbicides were positively correlated with nearby agricultural use for atrazine, cyanazine, alachlor, and metolachlor, but not simazine. Multivariate analysis demonstrated that for these five herbicides, frequencies of detection beneath agricultural areas were positively correlated with their agricultural use and persistence in aerobic soil.

5.4 Persistence

Persistent herbicides extends the period of weed control, increasing the efficiency of weed management efforts. However, they may persist longer than desired and kill subsequent or rotational crops (Colquhoun, 2006), in addition to polluting the environment. The persistence of soil-applied herbicides is known to vary considerably between different soil types as well as climatic regions (Rahman et al., 2011). Some herbicide families that have persistent members include the triazines, uracils, phenylureas, sulfonylureas, dinitroanilines, pigment inhibitors, imidazolinones, and certain plant-growth regulators.

5.5 Health hazards

Improper handling of herbicides by applicator or uncautioned exposures to field just sprayed with herbicides, and drift of herbicides during aerial application can pose occupational hazards and health risks. Some herbicides have been reported to have genotoxic, teratogenic and carcinogenic properties, while other have negative impacts on reproduction in animals and man, in addition to skin and eye irritations (Eisler, 1989; McGregor et al., 1998).

6. Benefits of non-chemical control of weed

Non-chemical methods of weed control have been found beneficial both economically and ecologically. We itemise the following benefits:

- Less harmful on applicators
- It is pollution free
- Beneficial and non-target organisms are not harmed
- There is no risk of pesticides residues on crops
- Cost of chemical is eliminated in the production costs.

7. Limitation to use of non-chemical weed control methods

Despite the identified ecological/environment and health benefits associated with non-chemical methods of weed control, it usage among the smallholder farmers are limited by a number of factors ranging from farmers perception to socio-economic considerations. Some of the identified limitations are:

- There is the problem of farmers' acceptability of non-chemical technologies because of perceived ineffectiveness (Okrikata & Anaso, 2008).
- Farmers' inability to evaluate the negative impact of synthetic chemicals on the environment and human health (Oruonye & Okrikata, 2010).
- Non-chemical weed control relies primarily on tillage and hand weeding, practices which are labor intensive and expensive (Gianessi & Reigner, 2007). Lack of available labor, and high wage rates prohibit use of these techniques for agricultural production. Wilson et al. (2009) posited that farmers understand, but often do not practice IPM/IWM for personal and socio-economic reasons. He emphasized that greater and wide adoption of IWM may be achieved by greater attention to the farmer's perspective, needs, belief structure, aspiration and belief structure.

8. Educating farmers on eco-friendliness of weed management in organic farming

Extension education can be defined as an informal out -of- school system of education designed to help rural people (especially farmers) to satisfy their needs, interests and desires. It is considered as an aspect of adult education directed to bring change in what people know and how people react to situations. One of the means extension education achieve its aims is adoption and diffusion of technology (application of knowledge for practical purpose which is generally used to improve the condition of human and natural environment and carry out some other socio-economic activities; Swanson, 1996) and innovation (idea, practice or product that is perceived as new by the potential users/adopters; Roger, 2003). All technologies, ideas and practices have origins or starting points and will be treated as innovations in a domain until its popularity is overwhelming. Weed management in organic farming or non-chemical based weed management method is a form of technology/innovation that needs to be transfered to farmers as end users for proper adoption and diffusion.

The process of diffusion is made of the target system which includes people in their various groups and sub-groups; the technology which is in the form of idea, skill or information found desirable, adoptable and adaptable to the target system; and the extension system comprising of the technology packager and communication specialist (Adekoya & Tologbonse, 2011). Diffusion is a precursor to adoption but not necessarily always ending up with the latter; it begins with the actual entry of an innovation into a target system, however, this can be passive or active. The passive one usually takes the form of innocuous information exchange often as a result of human movement form one system to another and the resulting casual interaction which subtly impinges on individual characters and influences the level of modernisation at individual level. Subsequently, folks observe this modernisation and sometimes emulate the development of the system's results.

However, as the passive diffusion continues, active diffusion that requires a more technical approach because it is consciously done with purpose in mind is advocated.

The extension personnel, in this wise, represents the source of information and this behooves of him/her to have a complete knowledge of the information/technology from the onset. With professionalism, the extension personnel understudies the target system and thereby determines the appropriate entry point which many be individual, a group or any other medium (Adekoya & Tologbonse, 2011).

Most farmers are said to go through a logical, problem-solving process known as adoption process when considering any new technology/innovation, the decision about whether or not to adopt a recommended agricultural practice is recognised to occur over a period of time in stages rather than instantaneous. The adoption process, according to van den Ban & Hawkins (1996) consists of the five stages that an individual goes through in adopting an innovation.

Awareness stage starts when the individual first hear of find out about the existence of the innovation, the individual at this stage lacks details concerning the way it works, how to use it and also the cost and benefits of the innovation apart from probably knowing its name.

Interest stage is when the individual develops an interest and actively seeks further information about the innovation such as how it works and what its potentialities are. The individual is very much interested in the cost factors and the time it will take to get the investment back if adopted.

Evaluation stage is when the individual weighs up the advantages and disadvantages of using it by going through a mental evaluation by asking self questions such as 'Is it worth it?' 'Can I do it?' 'Do I have enough resources?' 'Will it be beneficial to me and my family?' if the advantages outweigh the disadvantages especially with regard to the capital outlay against what else they might do with the same amount of money and the satisfaction they will get from these alternatives. This stage is terminated when an individual makes a decision whether to reject or accept the innovation.

Trial stage is usually experienced by most individuals that decide to accept the innovation and involves the testing of the innovation on a small scale to determine the relevance and usefulness of the innovation. This is in order to answer questions asked in the evaluation stage.

Adoption stage is the final stage when the individual applies the innovation on a large scale and continues to use it in preference to old methods. This, however, does not mean that the adopter will continue to use the innovation forever but will tend to use it until when a better innovation comes along or has a problem with the present one due to some other reasons. The stage is based on the mental or practical evaluation by the individual to make a final decision as to whether to adopt or reject. The above mentioned adoption process may be code named "AIETA" which is an acronym for Awareness-Interest-Evaluation-Trial-Adoption stage. The adoption process may therefore be defined as the acquisition and processing of information about an innovation followed by a behavioural change. This process stated above does not always follow the sequence in practice and depends on the technology and the individual in question. The most frequently skipped stage is the trial stage, on a practical note the farmer is hardly alone in deciding to adopt an innovation as the AIETA model may suggest; decision to adopt is usually taken in situations where farmer are in groups with members influencing one another (van den Ban & Hawkins,1996).

Oruonye & Okrikata (2010) opined that farmers' inability to evaluate the negative impact of synthetic chemicals on the environment and human health is one of the major challenge to the adoption of non-chemical methods of weed control. Provision of information to the farmers through quality extension service will facilitate their awareness and adoption of non-chemical weed management practices. In developing countries where a large majority of the farmers are illiterate and rural dwellers (Koledoye et al., 2013), the starting point will be to create an awareness of the hazardous effects associated with indiscriminate use of herbicides on the environment and also on human health.

Despite the pool of researches developed emphasising the econ-friendliness and sustainability of non-chemical use of weed control, a vast majority of smallholder farmers do not make wide use of them. From the foregoing, the poor adoption of some these non-chemical weed management practices can be associated with poor awareness on the availability and efficacy of these weed management options. Agreeably, there are cultural and other physical/mechanical control methods the farmers use and are very familiar with; however, most farmers in developing countries usually characterised by small holder agriculture, lack the capacity and knowledge to incorporate these methods in a systematic way to develop an integrated weed management strategy.

In educating farmers on eco-friendliness of weed management methods in organic farming, it is assumed that the mass media had direct, immediate, and powerful effects on the mass audience as it spreads knowledge of the innovation to a large audience rapidly and could even lead to changes in weakly held attitudes (Fliegel, 1984); but diffusion theory argues that, since opinion leaders directly affect the tipping of an innovation like weed management methods in organic farming, a powerful way for change agents to affect the diffusion of an innovation is to affect opinion leader attitudes since strong interpersonal ties are usually more effective in the formation and change of strongly held attitudes (Wejnert, 2002). Research has shown that farmers' attitudes are developed through communication exchanges about the innovation with peers and opinion leaders. These channels are more trusted and have greater effectiveness in dealing with resistance or apathy on the part of the farmers.

Persuading opinion leaders is the easiest way to foment positive attitudes toward an innovation. Rogers (2003) & Dowrick (1995) explains that the types of opinion leaders that change agents should target depend on the nature of the social system. Social systems can be characterized as heterophilous or homophilous. On one hand, heterophilous social systems tend to encourage change from system norms, in the sense that, there is more interaction between people from different backgrounds, indicating a greater interest in being exposed to new ideas. These systems have opinion leadership that is more innovative because these systems are desirous of innovation (Abrahamson, 1991). On the other hand, homophilous social systems tend toward system norms, in the sense that most interaction within them is between people from similar backgrounds which presupposes people and ideas that differ from the norm as strange and undesirable. These systems have opinion leadership that is not very innovative because these systems are averse to innovation (Abrahamson, 1991). For heterophilous systems, change agents can concentrate on targeting the most elite and innovative opinion leaders and the innovation will trickle-down to non-elites. If an elite opinion leader is convinced to adopt an innovation, the rest will exhibit excitement and readiness to learn and adopt it. The process of adoption of weed management methods in organic farming will commence with enthusiasm rather than resistance.

In the case of homophilous systems, however, encouraging the diffusion of an innovation is a far more difficult business. Change agents must target a wider group of opinion leaders, including some of the less elite, because innovations are less likely to trickle-down. Opinion leaders who adopt innovations in homophilous systems are more likely to be regarded as suspicious and/or dismissed from their opinion leadership. Often, opinion leaders in homophilous systems avoid adopting innovations in hopes of protecting their opinion leadership (Greenhalgh, et al., 2004). Generally, in homophilous systems, opinion leaders do not control attitudes as much as pre-existing norms do. Change agents must, if possible, communicate to opinion leaders a convincing argument in favor of the innovation like weed management methods in organic farming that accentuates the compatibility of the innovation with system norms. The opinion leaders will then be able to use this argument, which will hopefully resonate with the masses, to support their own adoption decision.

Successful efforts to diffuse an innovation depend on characteristics of the situation; to eliminate a deficit of awareness of an innovation like weed management methods in organic farming, mass media channels are most appropriate and to change prevailing attitudes about an innovation, it is best to persuade opinion leaders. Furthermore, it is expected that homophilous social systems are likely to frustrate change agents with their resistance to innovation. It is only for heterophilous social systems that pushing an innovation to the elusive tipping point is a relatively easy thing to do.

Conclusions

The importance of adoptions and use of eco-friendly weed management methods in organic farming/non-chemical and integrated approaches to weed management has been emphasized. In addition to the growing concern for protection of environment, maintain biodiversity and protection of human and animal health, this approaches are also good ways of climate change mitigation. Extension education through the use of all available channels like mass media and opinion leaders will create awareness and increase the knowledge base of farmer on these desirable weed management methods which is expected to help them make informed choices and adopt these approaches on a wide scale for the management of weeds on their farms. It is recommended that establishment of demonstration plots, using a farmer participatory approach to showcase the efficacy of these methods among other methods should be employed by the change agents. The challenge with unguided and improper use of herbicides seems to be more prominent in developing countries whereas over reliance on herbicide is a challenge in developed countries. Legislations guiding the use of herbicides and other synthetic pesticide should be put in place in developing countries, while regulations that are in place in developed countries should be enforced.

Areas of further research

We recommend that surveys are carried to access the extent of damage caused, and information from surveys be provided to the public. This will help pass the pass across to all stakeholders better. Socioeconomic factors are important to farmers' adoption of the recommended practices. Although some research has been conducted in this area, more needs to done. Research on ways to synchronise and upgrade indigenous farmers' knowledge with the practices introduced to facilitate adoption of the practices is also necessary.

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