Case study

Strengths and Weaknesses of Non-chemical Weed Management Strategies in Vegetables Production

ABSTRACT:

Weeds are continuing to create problems for ~~the~~ vegetables growers more than ever before due to climate change and intensive cropping. This study aims to investigate the weed management strategies, their strengths and weaknesses and, scope for ~~further~~ improvements of Armidale community garden in New England region, Australia by taking an in-depth interview. Non-chemical weed management methods including mulching, hand weeding, tillage, grazing ~~were~~ are mainly used to tackle the weed infestation. Among them mulching with wood chips and hand weeding were considered more effective to minimize the weed competition during the critical periods of crop development but they could not reach ~~at~~a satisfactory level. Thus, further improvements by integrating a number of approaches simultaneously is needed to ~~can~~ control weeds more effectively and economically.

KEYWORDS: Weed Management, Integrated methods, Mulching, Hand Weeding, Tillage, Crop Rotation.

I. INTRODUCTION

Weeds are one of the major threats worldwide to conserve biodiversity. Weeds are plants unwanted in human-controlled settings such as crop fields, pastures, gardens, sports fields, lawns and parks (Sindel 2000). A plant wanted in a context may consider as a weed when grown in an undesirable situation (Lamp and Collet 1979). Ansong and Pickering (2015) stated that any plant outside the cultivable group which can adapt in a diverse environment and can reproduces rapidly is known as a weed. This project investigates the existing weed management approaches of a horticulture enterprise in New South Wales and recognizes the importance and areas of improvement within these strategies.

Weeds have a major economic impact on agricultural production. Weed adversely affects crop yield and quality, and impacts farm management and profitability. Weed infestation has ~~to~~ become a significant risk due to climate change and intensive cropping (Coleman *et al.* 2011). In agriculture, it has long been a concern because weed competes with desirable plants for resources such as nutrients, water, space, sunlight and ultimately restricts the plant growth (Lamp and Collet 1979, Sindel 2000). In addition, they can provide host and vectors for plant pathogens, nematodes, mites and insects. Weeds also have economic impacts on cosmetic, recreational and decorative goals such as lawns, parks, landscape architecture, golf course and other natural areas (Ansong and Pickering 2015). They may damage roads, drains, foundations and other engineering works (Lamp and Collet 1979). Some weeds cause irritation to skin or digestive system of human or animal via thorns, hair, prickles or burs (Sindel 2000). For instance, *Nerium* species have a poisonous chemical which are harmful for human skin (Berenger 2017).

Australia has been facing a great challenge in weed infestation which also increases fire risk and land management cost. Over 2500 weed species currently affects Australian environment (Berenger 2017). Willmott (2013) stated that "Having a great climate and geography, combined with a highly disturbed land-scape, increasing development, tourism and population growth makes all the necessary ingredients for a weed heaven". Unregulated development, intensive cropping and release of new varieties are making the weed problem worse. In Australia, weed management cost is estimated about $4 billion every year (Sinden *et al.* 2004). In addition, they are likely to do a considerable amount of damage to the environment (Sindel 2000).

Due to a sub-tropical environment and geographic location, the Northern Tablelands of New South Wales has a wider level of biodiversity (Ruttledge *et al.* 2015). A cool climate with high rainfall makes the state ideal for agricultural production as well as allows it to be a suitable field for weed domination (Willmott 2013). The region has a dubious honour of being home to the widely established weeds with continual new incursions. Conventional weed management by chemical herbicides has resulted in herbicide-resistant weed population

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(Preston 2000). Thus, cost effective, environment-friendly sustainable weed management tactics should apply to enhance the agricultural productivity and profitability in this region.

Australia has diversified horticultural crops that grow~~n~~ in intensive rotation, across the wide range of environments (Henderson and Andrew 2000). Weeds are the prime constraint in vegetable production. Application of ~~fertilisers~~fertilizers, irrigation may enhance the growth of weed in vegetables (Kristiansen 2003). Kristiansen (2015) stated that weed infestation can reduce yield in vegetable crop up to 70%. Controlling weeds in horticultural enterprise and gardens are expensive. However, weed management cost may vary with the weed species, soil types, crop varieties, growing seasons and other input products. The weed management cost ranged from 2-22% of total production cost in vegetable production (Sindel *et al*. 2011). Berenger (2017) evaluated that Australian vegetable growers need to spend $479 per hectare for weed management, which covers about 11% of total variable expenses. Weeds associated with pest and disease may cause greater economic losses for vegetable production (Kristiansen 2015).

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There are a number of weed control options currently available to Australian vegetable growers. These are categorized into chemical, mechanical and cultural weed control methods (Kristiansen 2015). Some techniques are applicable for reducing weed before crop establishment; some are useful after crop plantation and others for enhancing crop-weed competition (Kristiansen 2015). All methods are not suitable for all types of plant or all types of enterprise. Minimization of weed competition during critical periods of crop development is the main goal of most vegetable farmers. Many farmers integrate techniques from each of these groups into their farm to control weeds at a satisfactory level (Kristiansen 2015). To date, a considerable number of studies have analysed the effectiveness and affordability of different weed control methods. But a few studies available ~~that~~ focused on the weed management system of a vegetable farm in the New England region. The lack of available information about the effects of weeds and usefulness of the applied tactics have increased the need for further study on accessible weed management methods.

This study aims to describe the weed management systems of a vegetable garden in New England region to find out the strengths and weaknesses of these tactics. This study seeks information about why they use such kind of technologies and whether these strategies are economically sound. This report also highlights the needs and scope of improvement within these strategies to ensure a better management practice for future. The findings might make an important contribution in sustainable weed management system in vegetable production.

II. METHODS

The Armidale Community Garden in the New England region of New South Wales (NSW) was selected for this study. The garden is situated at 30.5252^0S 151.6648^0E in the northern tablelands of NSW (Wikipidia 2017). This is a mixed vegetable growing garden in Armidale which also cultivates a lot of flowers, berries and herbs.

The study was conducted through observation, interview and informal discussion with a key person responsible for weed management in this garden. The researcher personally visited the garden and interviewed Ms. Jo Leoni, Community garden convener and mainstay. One in-depth and unstructured interview was taken to collect the data. A tape recorder was used to record the conversation. The interview was designed to investigate the present weed control tactics, their strengths and weaknesses, economic benefit and, need and scope for further improvements. With the consent of the respondent, photographs of different weed management approaches were taken for further study. This in-depth interview provided a multi-dimensional view for exploring the respondent understanding, attitude and behavior about weed.

III. RESULTS

3.1 Armidale Community Garden

The Armidale Community Garden began in late 2011 to encourage people to grow their own food and promote local production (Anon). A group of enthusiastic Armidale community members came together and established the garden in a set of six clay tennis courts behind the New England Regional Art Museum (NERAM), which had fallen into disuse for many years. The community garden is an action group of Sustainable Living Armidale (SLA) and SLA's insurance covers ~~it's~~ all it's activities (SLA 2015). It's a shared garden that invites all community people to grow and harvest chemical free fresh vegetables, fruits, herbs and flowers. The garden becomes a great platform to connect with culture, share knowledge and promote health and well-being. Though summer is the main growing season, the garden covers with assorted colours of leafy vegetables, beans, tubers crops, spices, berries and fruits round the year. The volunteers who help in the garden can take some lovely

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fresh food away for free. Excess produce is sold, either directly from the garden or at the farmers' market in first and third Sunday of every month, which also provides the funds for garden activities.

Weeds become the main constraints of the garden by not only reducing yield and quality of the crops but also providing habitat for pest and lizards which hamper to work freely. Broadleaf weeds (i.e dandelion, clover, fat hen, buxbaum's, thistles, shepherd's purse, stagger weed), grasses (i.e kikuyu, couch, summer grass, winter grass, cocksfoot) and sedges (i.e nutgrass) are very common weeds in the garden. Among them, kikuyu, nutgrass, fat hen, dandelion and thistles are considered as problematic weeds for their persistent underground parts and rapid spreading capacity. The ~~informant~~ respondent is concerned about weed and considered it as a great problem. The growers have to put extra effort to control the weeds throughout the year. Although the amount of economic loss due to weeds was never estimated by the growers, they believe more production might be possible if the weeds can manage properly.

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3.2 Weed Control Methods

Various weed control methods are available in the community garden. The growers always tried to keep the garden chemical free. Sometimes they use a few pesticides for controlling the pest and diseases but they never use either chemical or organic herbicides for weed management. Mechanical and cultural weed management methods are mainly used to tackle the problem. The weeding methods investigated in the community garden are presented below.

3.2.1 Mulching

Mulching is the main weed management tactics ~~which~~ used in the garden for suppressing weed. Organic mulch such as wood chips, pine and spruce bark is commonly used in the garden (Figure 1). It is applied at a thickness of 4-5 inches between the beds and walkways. It was observed that the area covered by thick mulch is free from weeds while the uncovered area is continuingly getting weeds. That's why they tried to get ~~cover~~ the garden covered all the time. But the garden beds are not covered by mulch because most of the time a small worm named 'Spill bugs' remain in the bark. They can go up to the bed and can cut the seedlings. However, the decomposed mulches are mixed thoroughly with the soil during bed preparation. Mulches work on to inhibit the weed seed germination by preventing sunlight reaching to the seeds. This mulch also used for retaining the soil moisture and improving the soil health.

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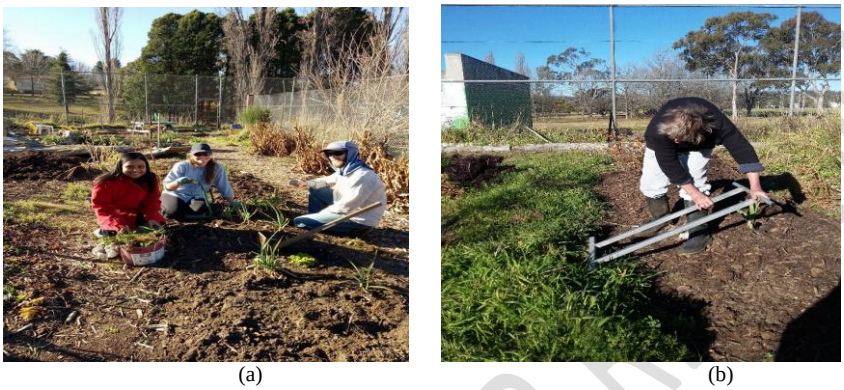
Figure 1. Organic mulch (wood chips) used in the community garden

3.2.2 Hand Weeding

Hand weeding is another common technique regularly used in the garden. Generally, in the growing seasons, the garden is weeded and irrigated ~~in~~ every two days. The weeds are pulled by hand or several types of hand weeder such as hoes, gardens forks and trowels (Figure 2a). The ~~informant~~ respondent said that most of the volunteers who work in this shared garden were happy to keep the vegetable beds free from weed~~ or any off type plants~~. Most of the time, the volunteers bring their own weeding tools. They removed the weed by hand-pulling or hoeing and pile up the weed for composting. Before dumping in the compost pit, the noxious weed, seeds and quick spreading grasses such as kikuyu are separated carefully to check the weed infestation (Figure 3).



(a) (b)

Figure 2. a) Hand weeding and b) Tillage used during bed preparation for weed management.

3.2.3 Tillage

Tillage during fallow and before sowing or planting is also an effective way to control the weeds. Before crop bed preparation, a deep ploughing is done to uproot the existing weeds from the soil (Figure 2b). Then hand picking is performed to keep the soil free from roots, stems, seeds and inert materials. Sometimes, tillage carried out immediately after harvesting to incorporate the plant residues to the soil. During the cropping phase, light tillage is also performed in between the crop rows. Spades, shovels, garden rakes, garden forks, mattocks and trowels were usually used for tilling. After tillage, the weeds as well as the green parts of the plant are used for compost~~ing~~ (Figure 3).

Figure 3. Selected weeds are used for compost production

3.2.4 Grazing

There is a little poultry shed where 12 chickens are reared in the community garden. They also ~~do little~~ help~~ed~~ to manage the weed by eating the green leaves, inflorescences and seeds of weeds. ~~Jo Leoni~~The respondent said that they never allow the chickens to graze the garden immediately after sowing or planting to the seedling stage of crops because they can eat seeds, little seedlings, and leaves which my hamper crop growth.

3.2.5 Crop Rotation

The respondent said that they tried to cultivate different crops species in a periodic sequence of the beds. For instance, last year they grew cucurbits on the north-west corner and this year the beds are prepared~~ing~~ for onion and garlic. Rotations provide less chance for the weeds associated with particular crops to adapt and survive. But there is no perfect cropping rotation system followed in the garden except changing the beds in every season. However, this practice plays a significant role in weed management by changing the environmental conditions for weeds.

3.3 Cost and Time for Weed Management

The r~~R~~espondent was unlikely to estimate the cost and time required for weed management. It was not clear which operations need how much money and labour. Since, it's a shared garden community people work here ~~free of charge~~for free. ~~Informant~~ The respondent said that during the cropping phase, 8-10 volunteers spend approximately an hour for hand weeding. So, there is no cost to labour except mulch. Around 15 cubic meters mulch is required to cover the garden to a thickness of 4 inches and the cost for mulch is about $330-350.

IV. DISCUSSION

Weed is one of the most significant obstacles to get desired vegetable production. The demand for integrated weed management has grown steadily in recent years among vegetable growers (Kristiansen 2003). Because ~~of~~ single management practice cannot control the weeds properly; the growers need to apply different controlling techniques simultaneously. The community garden also tried to control the weeds by applying different methods together. The most noticeable aspect of these strategies is that they are safe for the community and environment. Without using any kind of pesticides, weeds are being positively controlled during growing season. Therefore, there is a need to evaluate the efficiency and cost effectiveness of currently used weeding methods.

4.1 Strengths and weaknesses of existing weed management methods

4.1.1 Mulching

Mulches are very effective at suppressing weeds and restricting seed germination. Kristiansen *et al.* (2003) stated that mulch can control 80% of weeds of vegetables. It can improve soil health by retaining soil moisture, controlling soil temperature and increasing soil microbes. The decayed mulch can be used as fertilizer which increases the organic matter content of the soil (Billeaud and Zajicek 1989). The wood chips are relatively expensive but they do a lot of jobs for the garden. Thus, the method is an economically viable weed management option for the garden.

There are some problems experienced with mulch such as difficulties with application, and achieving uniform thickness. Mulch has negative impacts on crop growth and yield. Arentoft *et al.* (2013) reported that mulch can act as a vector for weed spread because weed seeds, tubers and other reproductive parts can easily transmit through the mulch. It also increased insects and disease activities in vegetable crops (Henderson and Andrew 2000).

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4.1.2 Hand weeding

Hand weeding is widely used weed control technique all over the world. Kristiansen *et al.* (2003) estimated that about 96% of weed could reduce by regular hand weeding. Good selective control of weed is another advantage of hand weeding which is not available with other methods (Kristiansen 2003).

It's a laborious and time-consuming method. Timing is also critical because many species can be regenerated from transplanted pieces if they become too large before hand-weeding (Asgarpoor *et al.* 2011). In the community garden, hand weeding is mainly depended on volunteer's activities. In extreme hot, cold or rainy weather the numbers of volunteers were reduced which resulted in irregular weeding. Then it was difficult to restore the garden to its former state.

4.1.3 Tillage

Tillage before sowing or planting was universally used by vegetable growers due to its high effectiveness and affordability (Pannacci *et al.* 2017). Kristiansen (2003) estimated an average reduction of weeds by 66% for

tillage. Tillage can play a key role to destroy new colonies of weeds before establishing in a suitable environment (Pratley 2000).

The effectiveness of tillage depends on tilling time, tilling equipment, knowledge and skill of farmers (Pratley 2000). Excessive tillage can reduce soil quality and crop yield by damaging root system (Kristiansen *et al.* 2003). Tillage often breaks the seed dormancy and encourages germination of new weed cohorts (Kristiansen 2015).

4.1.4 Grazing

Grazing is moderately effective and affordable method of weed management (Kemp and Friend 2000). By eating the leaf, soft stem, flower and seed the chickens could make the weed less competitive to crop.

Grazing at seedling stage and excess grazing can reduce plant growth that's why grazing time should be controlled (Kemp and Friend 2000).

4.1.5 Crop rotation

Crop rotation is commonly used in the vegetable garden for insect and diseases management. Most of the enterprise considered weed management to be~~is~~ the secondary objective of crop rotation (Kristiansen 2015). It is moderately effective but highly affordable weed management tool for controlling many broadleaf weeds.

The disadvantages of crop rotation are that it is not being able to grow highest value crops. Farmers also require~~d~~ knowledge of weed, their favorable environment and skill to maintain proper crop rotation.

In addition, farm hygiene is not maintained properly in the garden. Everybody has the access to the garden. The visitors and volunteers can easily spread weed through their shoes, tools and vehicles. Sindel *et al.* (2011) stated that poor hygiene practices can allow weed infestations in a farm that were previously relatively weed free. Sometimes, weed's reproductive parts remained in the composting materials which also help the weeds to spread again.

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4.2 Future Problems

Undoubtedly, weed management is a continuous battle for the vegetable growers. They need to face many more weed management challenges in future. The following problems may arise in the future:

- In Australia, most weed species have been introduced from overseas and every time new species are being added to the list. The abundance and distribution of new weed species may increase in the garden.
- By adapting to the environment some minor weeds can become major weeds in the near future and can increase their economic impact.
- Climate change can be major influences to spread, adaptation and abundance of weeds in the garden.
- The existing farming system such as intensive cropping and weed management systems such as mulching can increase weed infestation.

4.3 Recommendations

Although the growers are constantly trying to keep the community garden free from weed, still they cannot reach a~~t~~ satisfactory level. To be able to solve this problem, there may be a need for improvements in the current weed management methods. In addition, to face the future challenges more effective and economically sound weed control strategies should be practiced in the garden. The garden should practice sustainable weed management methods which will be safe both for the community and the environment. No single technique alone will efficiently control weeds during the entire cropping season (kristiansen 2015). Thus, integration of a number of methods are the best way to ensure a sustainable management system. By incorporating the following strategies, the existing management practices can be improved.

- To be able to control the weed effectively, understanding and knowledge of the biology and ecology of weeds are necessary. The developments of recent technologies such as the internet, computer and mobile have created several new and effective tools for weed identification, learning weed habitat and improving new control methods. The growers can improve their knowledge through these modern technologies.

- Maintaining farm hygiene is obvious for control weeds in the garden. Farm hygiene practices can successfully limit ~~the~~ weed infestation. A range of techniques such as equipment cleanliness, restriction of movement on the garden and careful product (seed, mulch, compost) selection might reduce the spread of weeds.
- Planting cover crops or green manure crops can be an effective and profitable technique for this garden. They can grow lablab, mungbean, cowpea, and fava bean to cover the beds outside the cropping season. Dense cover crops are effective to suppress weeds (Kristiansen 2003). It may also improve soil quality and structure, increase soil organic matter, reduce soil erosion and increase agroecosystem diversity.
- Bio fumigation will be another possible practice for the growers. Some Brassicaceae crops such as Indian mustard, fodder radish, fodder rape and canola release fumigant-like compounds into the soil when decomposed. These plants contain a lot of glucosinolates (GSLs) and after breaking down it can produce isothiocyanates (ITCs) which are responsible for the phytotoxic effects on weeds (Eberlein *et al*. 1997 as cited in Kristiansen 2015). It has a positive impact on weed as well as insects and diseases control. During the fallow season, bio fumigants can be planted in the garden and before crop cultivation; they can be mixed into the soil.
- By increasing the density of the crops, the growers can create a competitive advantage over the weeds. The vegetable crops which can produce a closed canopy can prevent the light to reach the ground (Bajwa *et al.* 2017). Then it will be difficult for weed seeds to germinate under a dense canopy. However, this will be useful for the broad leaves vegetables.
- Growers are suggested to apply bio herbicides or organic herbicides because they are not only effective but also safe for human, animals and environment. Different types of essential oils such as eucalyptus oil, pine oil, neem oil, vinegar, salts, and crushed mustard seeds are the available options of bioherbicides (Sindel *et al.* 2011).
- Understanding the knowledge, attitudes and behavior of community people is important to develop sustainable weed management methods because they are the main driving force of the garden. Weed management will not be effective without the support of volunteers and visitors. They could be encouraged to take personal initiatives such as using separate~~d~~ shoes or covering up socks to reduce the spread of weed in the garden.
- To adopt a cost-effective method in the garden, the yield loss due to weed and management cost of each methods should be estimated properly.

Overall, integrated weed management system that combines appropriate chemical, mechanical and cultural methods should be practic~~s~~ed in the garden. Regular monitoring will be needed to reduce the weed infestation because once the weed spread, it will be very difficult to control.

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Comment [IO11]: How does this impact yield?

V. CONCLUSION

Weeds are the major constraint to get desirable yield and profit from agricultural production. Vegetable growers have to face more challenges to get rid of weed infestation. Weed management tactics may vary with weed species, crop varieties, seasons and enterprise goal. In this study, the present weed management strategies of a vegetable garden ~~were~~ critically analyzed by ~~taking~~ in-depth interview of the key person responsible for managing weeds. Mulching with wood chips was the main ~~tactics~~ method ~~that~~ used in the garden. In addition, few conventional methods such as hand weeding, tillage were applied to reduce the problem. Though the methods had high effectiveness and affordability, the growers were not able to control the over spreading weeds properly. Thus, further improvements are needed within the approaches. Since the single method is not sufficient to tackle this problem, systems integration is required to reduce the possibility of weed control failure. Along with the existing strategies, planting cover crops, applying organic herbicides and using bio fumigation are recommended. By practicing integrated weed management approaches, the vegetable growers can control weeds more effectively and economically. Community involvement in weed control process will sustain the improvement. Further research is required to determine the impact of weeds including the yield and quality decline, weed management cost and their effectiveness in the garden. Therefore, to meet the future challenges weed managers need to think beyond and be flexible in their approaches to weed issues.

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