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Guideline

Improvement of pesticide use and application in Hayanist

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Chapter I Introduction

In Armenia, it is impossible to cut down the use of pesticides to zero and completely use the biological control. Because the current situation in Hayanist does not support to reach the aims due to many limitations, e.g. the lack of knowledge, poverty, unsuitable agro-environment, and uncertainty and insufficiency in agricultural related legislations (document from the ministry). However, the basic aim of our project is to improve the pesticide use, not to cut down to zero, so there is no need to reduce the pesticide use sharply in short time. It is better to combine the best methodologies of IPM and organic agriculture which are fit most to the current situation of Hayanist. We can make a model to predict the future pest control in Hayanist Armenia for about 10 years. From the graph 1 below, it is easy to find that the chemical control is reduced year by year and the biological control gradually increases therefore it is better to divide the whole time into three periods.

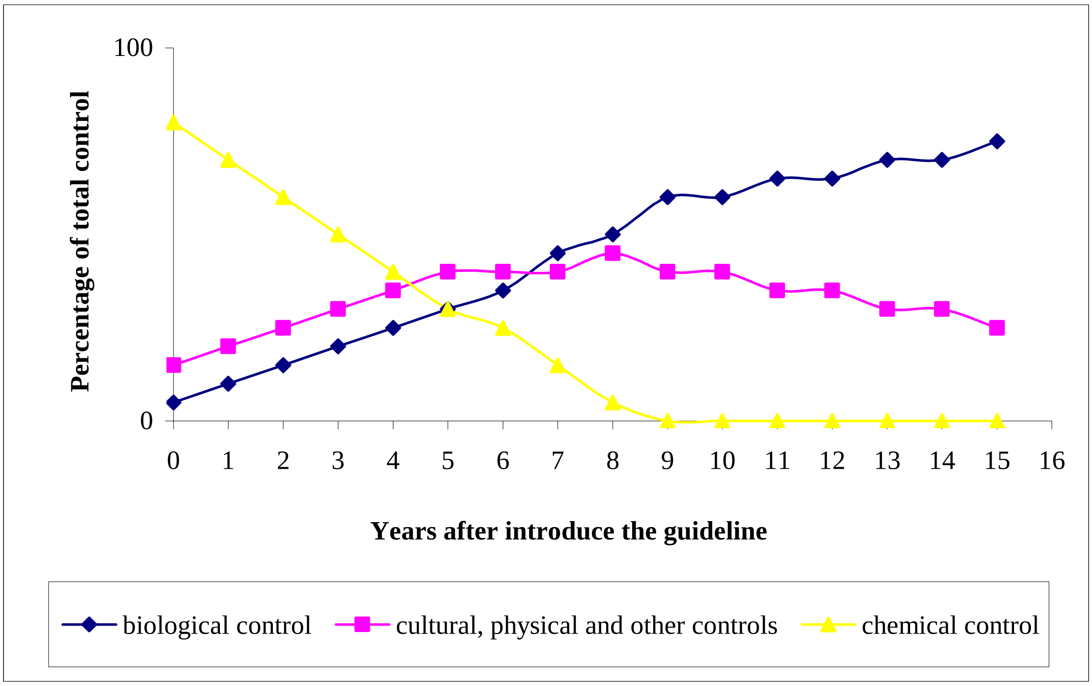

Figure 1. Different pest controls in Hayanist Armenia in the future

In the first period, form 0 to 2 or 3 years, the villagers can not reduce the usage of pesticide rapidly because of many limitations. Also in this stage the introduction of integrated pest management (especially biological control) is accepted by the farmers gradually, so that it needs several years to try or to accept the new methods for the farmers. Therefore in this period we can use many methods to convince villagers and build the basic trust. At the same time it is better to educate farmers to have a good agricultural practice thus they know good pesticide application practices and good ways to culture their crop. From the graph we can see that the percentage of biological control usage is quite low, therefore if we want the villagers to reduce the usage of pesticides, we can teach them some simple and cheaper methods to replace the use of the pesticides such as the physical and mechanical pest control and basic cultural control. It is also possible to introduce to natural pesticides which are less harm for both the crops and the people. At the same time, some practices of organic agriculture might introduce such as the improvement of soil quality by addition of organic matter and the internal recycling of resources. Nevertheless, the criteria for selecting organic agriculture practices are: 1) they should not interfere with the process of integrated pest management; 2) that practice takes long period for achievement and it is important for the long term improvement.

In the second period, most of the villagers would trust the new technology thus we can give further information about the introduction of other technologies. In these several years farmers can use the complete cultural pest control and at the end of this stage they could use the biological control completely. Because the villagers can see the profit from using the new methods, therefore the pesticides usage will decrease rapidly. We can find from the graph that at the end of this stage the chemical control will drop almost to 0. At that time what they will use is the biological control combined with other non-chemical controls. All the controls are integrated, and that is the real integrated pest management (IPM).

After the second period, hopefully we can reach our project's basic aim: improving the use and application of pesticides in Hayanist Armenia. However, the development can be continued in order to reach the pesticide-free environment. At the end of the second period and the starting point of the third period, it is the stage of organic agriculture. From the start point of this period, the farmers can combine all the factors in their farms and change them to the real organic farms at last and continue the positive loop. Hopefully at last both the villagers and the Armenian government would find the final benefit by using these ways. The environment would be better and healthier for the human being.

Table 1
The starting time of each method

Years after introduction of the project	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Chemical control															
Human protection and safe pesticide use															
Physical & mechanical control															
Crop rotation															
Cropping system (inter, trap)															
Biological control (natural enemy)															
Organic agriculture															

We divide this period into two parts: short term and long term. In the short term, the methods can be used as soon as possible. The methods are: optimal pesticides application, human protection and physical or mechanical control. The long term methods are used several years after using the short term. We can see the detail steps or methods in the table 1 above. From the table, you can find the start time for each method clearly.

Chapter II Short term solution

2.1 Protective equipments

2.1.1 Entry routes of pesticide

Pesticides do not only have the dangerous effects on target pests, but most of the time they also cause serious harm to other organisms including human. Concerning pesticide users, there are several routes that the users can up take pesticides. While applying pesticides, human skin such as area of hands, arms, face, head, and eyes can absorb the substances which are the most significant routes of pesticide contact to human. Below is a picture of Dermatitis-a rash cause by direct exposure to pesticides.

Figure 2. Dermatitis symptom caused by direct exposure to pesticides

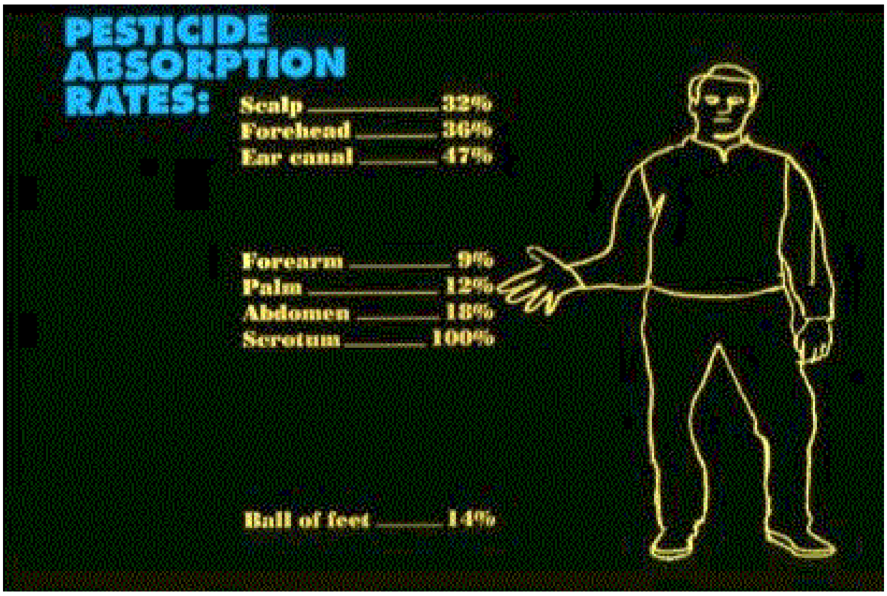

Figure 3. The absorption rate of pesticide varies according to body parts.

Different parts of human skin have different rate of pesticide susceptibility. The study shows that the most susceptible part of human is scrotum. This part has the fastest rate of pesticide absorption (Figure 3). However, hand is part of the body that most of the time has direct contact to pesticides and it can transfer pesticides to other part of the body such as by rubbing the eyes. Moreover, inhalation and oral up taking are also the other common route. Symptoms of pesticide poisoning are ranged from headaches to vomiting and even death (Pesticide protection, 2005). Therefore pesticide users must know the ways to protect themselves against the poisonous substances.

2.1.2 Factors concerned for selection of protective equipments

The selection of protective equipment depends on the type of chemicals and situations. Therefore, it is very important that users read pesticide label properly. The first things that users have to know are toxicity, routes of entry, and formulation of a particular pesticide. All of this information can be found in the label of authorized pesticides. For the toxicity, it is usually divided into three groups, i.e. high toxic, moderate toxic and slightly toxic. Moreover, it also gives the information on the common routes that a particular pesticide can contact to human. Body parts indicated by the label therefore need intensive protections. The combination of this information suggests user for protective types. Such as, a high toxic pesticide to the inhalation needs different protective equipment from that for dermal toxicity. If a pesticide label does not have specific personal protective equipment (PPE) requirements, the route of entry and specific action statements from the label can determine the type and degree of protection that are needed to handle the pesticide safely.

Formations of pesticides also an important factor to be concerned. The types of formulations are dry, liquid, and aerosol. The water-based pesticide requires only water proof material for protection, but the formulations that are not water-based require chemical resistant protective material. The label might also provide protective equipments that required for a certain pesticide. Normally liquid pesticides are often more hazardous to use than dry formulations, and that extra protection is needed while mixing or loading pesticides.

2.1.3 Personal protective equipment (PPE)

Protecting suits

- Underwear and regular work cloths: The more layers worn, the better protection it is. General type of cloth is long pants and a long- sleeved shirt. Shirt has to be fastened at the neck. Sleeve should cover gloves as well as pant legs cover boots. To provide the maximum protection based on work cloth, the cloth should make from twill fabric (denim) or 100% cotton. Heavy and thick cloth is better than the lighter one. Moreover starch finish can also spray over surface of cloths to provide the protective layer. There are many brand of starch such as Fybrite® (FIGH-bright), Scotchgard®, and Zepel® (zeh-PEHL).
- Coveralls: When the ordinary suit is not enough, the pesticide handler can consider additional protective suits as provide in the label of pesticides. The pesticide user might consider coveralls of woven fabric, coveralls of non-woven fabric. Coverall provide the protective through out the body except head, palms and feet. It can be worn over a clean working suit. Woven coveralls are made from sturdy cotton or

cotton/polyester fabric. They can be laundered and reused. Non-woven fabrics have a random orientation of fibers, which prevents paths that pesticides can follow through the fabric.

- Chemical resistant suits: Chemical-resistant may be required for liquid pesticides that are formulated with solvents other than water-such as xylene, and alcohol, or for high-exposure situations.


Figure 4. The extra protective layer, apron

- Aprons: Chemical-resistant aprons (Figure 4) provide an extra layer of body shield for mixing and loading or for cleaning equipment. They also prevent contamination of the handler's other clothing. An apron protects against spills and splashes to the body. Other separate sleeve guards to protect forearms can be added.

Head gears

- Protective hood: In some protective suit, a hood is provided. The hood should be made smooth and cover head and neck area. Best ball cap should not be used because it becomes accumulating source of pesticide, or if it is necessary, the laundry should be done often to prevent repeat contaminations. When the hood is not in used, it should be kept to prevent the unnecessary exposure (source; USDA).

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Eyewear


Figure 5. Snug-fitting goggles

- Eye protection: An eye protection is needed when the chemical indicate an eye hazard. Safety glasses with brow and side shields are suitable for most exposure situations. This kind of glasses is not expensive and does not cause fogging or sweating. Snug-fitting goggles or a full-face respirator give better protection. It is recommended when applying mists, fogs, or aerosols indoors. Precaution: Contact lenses should not be worn during pesticide application. Face shield that cover the face and throat can prevent the cover area from splashes. In the severe exposure situation, face shields can be worn over goggle (source; USDA; Boland. 2004).

Respirator

- Inhaling protection: Normally this kind of protection is needed when the pesticide is in the form of aerosol, mist or dust. The basic protection is filtering face-pieces" or "particulate respirators". The filtering face-piece in cup style has two straps for a secure fit. It may also have an adjustable


Picture 6. Particulate respirators

nosepiece, a nose cushion, and an exhale valve for comfort and fit. It has two head straps for a tight fit and may have a valve for breathing. When resistance of the filter becomes excessive, wet or damaged, it should be replaced. In the hazard situation such as working with the mist of oil, organic vapour and gasses, half- and full-face cartridge respirators is needed. It uses cartridges, filters, and prefilters to filter air. The specific respirator is suitable for a certain type of pesticide. According to PPE (Personal Protective Equipment), there are three types of respirators, i.e. N=not resistant to oil, R=resistant to oil for 8 hrs, and P=oil proof, and resistant to oil for more than 8 hrs.

Hand and footwear

- Gloves: Unlined gloves of any plastic or rubber material sturdy enough to remain intact during the job is suitable for dry or water-based pesticide. The other acceptable materials are natural rubber (latex), polyvinyl chloride (PVC), neoprene, butyl, nitrile, or barrier laminates. The material that is not suitable for pesticide protection are cotton and leather. Leather accumulates pesticides and cannot be clean. For non-water-based liquid pesticides, chemical-resistant gloves are recommended. In the case that specific material is not specified, gloves made from nitrile, butyl, or a barrier laminate such as Silver Shield. Barrier laminates give the best protection.

- Footwear: In the case of pesticides that label 'Waming or Danger for dermal toxicity' wearing unlined, chemical-resistant footwear is essential. It is also sensible practice for all pesticide application. The footwear should be non-skid boots make of PVC, natural rubber (latex), neoprene, and nitrile. However, latex is only effective with dry or water-based formulations. Shoe covers of non-woven fabric may be worn (Boland, 2004; USDA, 2005).

2.1.4 Other tips

- Garments have to check for defects before reuse. Protective clothing is useless and may even be harmful, if not properly used and maintained. Gloves can be checked for leakage by filling gloves with water or air. Protective suits should be checked for rips and split seams.

- Labeling the usage period of equipment. The material absorbs pesticide over time. Therefore they should be discarded at a certain time.

- As soon as the job is finished, the garment should be cleaned even before removing them from body. The outside of your gloves and boots should be washed with detergent and water before removing them. Then inside and outside of gloves and boots should be cleaned with more detergent and water. After washing, the garments are rinsed thoroughly and dried in a well-ventilated area.

- The shower should be taken soon after the removal of garment and before changing into new cloth. Make sure to use plenty of soap and water. Hair and fingernail should be cleaned thoroughly.

- Reusable garments such as protective cloth, underwear and coverall should be washed daily. Hot water should be used while washing, and cold water is for rinsing. Separation of the contaminated cloth and cleaning them separately form other cloth would be the best way.

- If garments cannot be washed immediately, they should be hanged in the open area where pet and other animal cannot reach. Sunshine will help to breakdown the chemical.
- To dry cloth after washing, drying the cloth in open air is better than drying them by cloth dryer. Then the cloth should be store separately from other clothes. Therefore any chemical that might remain in the cloth cannot contaminate other.
- To discard garments, it should be cut into pieces to prevent reusing.

2.1.5 Protective equipment recommended for specific pesticides found in Hayanist

- Karate: It is the water-based pesticide (Syngenta, 2005). Since spraying is the way of apply this pesticide, the applier needs the protective equipment that is water proved, i.e. gloves, glasses and normal filtering face-piece.
- Metaphos: Wear chemical safety glasses/goggles or faceshield. Half-face respirator, with organic vapour cartridge should be used. Chemical handling gloves should be PVC or Nitrile (source: Ameron coatings).
- Chlorophos or metrifonate: It is mostly provided in forms of water-based spay and dust. It can be readily absorbed via skin, ingestion, and inhalation. Therefore the protective equipment that can protect skin (made from water-proved material) nose and mouth are specially needed (source: Inchem; health and safety guide).
- Dimetoate or dimithoate: For all formulation of this pesticide the protective clothing should be used as well as the particulate respirator.
- Confidor: General protective clothing is required. Contacting with eyes, skin and clothing during mixing and spraying operations must be avoided. Do not inhale spray mist. Special personal protective equipment is not required, but full length overalls recommended as standard practice.
- Actara: Long-sleeved shirt and long pants; chemical resistant gloves made of any waterproof material; shoes plus socks.
- Dursban: Applicators and other handlers must wear long-sleeved shirt and long pants and shoes plus socks (source: Dursban*1%)
- Endrin: Standard protective clothing, eyes protection. Exposure over 0.1 mg/m^3 the full face respirator(MSHA/NIOSH) with cartridge and prefilter is requried.
- Aldrin: Standard clothing, chemical resistant gloves. Exposure over 0.25 mg/m^3, the full face respirator (MSHA/NIOSH) with cartridge and prefilter is required.
- Lindane: Beside the standard clothing, chemical barrier glove made from laminate, nitrile, or neoprene rubber. Handling with concentrated chemical, coverall, chemical resistant gloves, apron, shoe and sock should be used.

2.2 Pesticide application

The general aim of pesticide application is to bring pesticide directly to the target pests or diseases and give the minimal damage to non target organisms. In order to effectively apply pesticides, there are several factors that the users should take into account. Pesticides should be applied when the factors below are concerned (Boland *et al*., 2004);

- the right choice of pesticide products
- the right concentration and amount
- the right time
- determination of pesticide application effectiveness
- Harvest interval

The right choice of pesticide products:
Before decided to purchase pesticides, users have to determine the situation wether pesticide is really needed (source: Use pesticide wisely).

- Users have to determine weather the damage is really caused by pest not by the environmental factors or cultural practice.
- If the symptom is caused by insect, users have to determine what kind of insects.
- Users have to decide the type of pesticide that the active compound is suitable for a particular insect species. Normally, the label of pesticide product provides the target organism of a certain pesticide type. In addition it also provides the type of plant that is most appropriate for a pesticide. Therefore the label should be read carefully.
- Users have to make trade off whether the cost that causes by pesticide application is lower than the cost that causes by pest damaging.

The right concentration and amount:
Pesticides should be used in the appropriate amount to control the harmful pest effectively while giving the least side effects to environment and non target organisms. To achieve this aim, calibration must be done based on information below (Boland, 2004).

- Recommended dosage of active intergradient per hectare; the recommended dose can presented in two forms, i.e. Percent (%) concentration of active intergradient in the spray solution, weight (gram) or volume (liters) of active intergradient per hectare.
- Amount of spray liquid per hectare
- Percentage of active intergradient in the commercial pesticide formula
- Application area expressed in hectare

Example: Usually pesticide provides in concentrated form, therefore before using, users have to know how to prepare pesticide mixture. This example demonstrates the calculation (Boland, 2004).

1. Users have to know the capacity of their equipment. The capacity express in term of ‘area sprayed’ which is expressed in hectare.
   - Users have to know the ‘width of spray swath’(such as 1.5 m)
   - Users have to know the ‘length of test run’. This can be found by filling the spray tank with known amount of water (such as 2.5 liter). Start to spray the water constantly until the tank is empty. After spraying, user measures the length of the test run (such as 50 m).
   - Then the area sprayed can be calculated by the formula

Area sprayed = (width of spray swath * length of test run) / 1000

Area sprayed = (1.5 * 50)/1000 = 0.0075 ha

2. Then users have to know the application rate.

Application rate = volume sprayed/ area sprayed

Application rate = 2.5(l) /0.0075(ha) = 333 liters/ha

Therefore at this point user will know how much pesticide mixture wanted for full area application. Such as users grow their crops in the area of 2 hectare; therefore they need the final volume of mixture of 333*2= 666 liters

3. Users have to know the ‘spray load’. The spray load means how many times that users have to refill the spray tank in order to spray the full area.

Spray load = application rate / tank capacity

Spray load = 333 (liters/ha)/ 10 liter = 33.3 times

Therefore according to the example, in order to spray 1 hectare area users have to reload the pesticide 33.3 times.

4. If the label tell that a pesticide should be apply at the rate of 1.5 liter/ha (or 1.5 kg/ha), user have to dissolve 1.5 liter or 1.5 kg of pesticide in 333 liter of water. And therefore he can use this amount of pesticide mixture in the area of 1 hectare. Nevertheless, users can calculate the amount of pesticide needed in one spray load by the following formula.

Amount of pesticide needed per spray load = recommended dosage (liter/ha or Kg/ha)/ spray load

Therefore in each spray load of 10 liter (capacity of tank), user should use:

Amount of pesticide needed per spray load = 1.5 liter/33 spray load
= 1500ml/33 spray load
= 45.5 ml or grams

Thus 45.5 ml or grams of pesticide are dissolved in 10 liter of water per spray load.

The right time:

Factors needed to take into account to determine the right time of action are:

- Growth stage of crop: usually in the early stage of crop growth, plant is more susceptible than the later stage. The bigger crop the more leaf surface. Therefore the more amount of pesticide is needed.
- The kind of pest present, developmental stage of pests, and amount of pest infestation: Users have to determine the threshold in order to decide the right time of application. Generally the threshold is done by calculating the infestation rate via calculating the number of insects on the sample plants taken in diagonal line in the field. When taking the samples, the developmental stage of pests can also be observed. Thus, user can select pesticide that is the most appropriate to pest stage. Amount of natural enemy is also important to find out. If the amount of natural enemy is high, pesticide action might not necessary.

- The environment is also the factor determining the efficiency of pesticide application. User should select time that harmful organism is the most effective. However, User prohibits spraying in the strong windy environment and being against the wind since the spray mist can drift on the sprayer. Therefore it is recommended spraying in the morning or evening since it is less windy and pesticide is less likely to evaporate. Do not spray in the rainy or expected rainy. If it is no wind at all, it is also not good since wind will help to carry pesticide through plant canopy. In the environment with strong sunshine, the spraying is also prohibited.
- After pesticide application users have to pay attention on the following information
  - Marking the spray fields and re-entry interval. The re-entry interval signifies the period of time that must past, before human who doesn't wear protective clothing can enter the area.
  - Recording the dosage per ha
  - Recoding peculiarity such as effect of wind or rain
  - Paying attention to the period that the safe harvest can be done (Boland, 2004)

<u>Determination of pesticide application effectiveness</u> (Boland, 2004)

In addition, checking the effect of pesticide application is also necessary. This can be done by the following steps;

- Make the estimation of number of insect per plant in the day before pesticide application
- In average, pesticide reaches maximum effect 3 days after application. Thus after tree day, the insect estimation can be done again
- If more than 1% of pest still alive, the repeat of application in the same dosage should be done
- If most of pests have survived, the users have to find other method which might not be the chemical option. The mistake of the application should also be found out, such as by asking the experienced users

<u>Harvest interval</u> (Boland, 2004)

In the label of pesticide it indicates the period of time that harvesting is allowed. Before the indicated period, pesticide still active and therefore it gives side effects to human who consume agricultural products. Different pesticides have different degrading time. It depends on intergradient. Usually pesticides are degraded according to wind, sunshine or drift off by rain.

Chapter III Long term solution

3.1 Integrated Pest Management (IPM)

From the information of using and handling of pesticides (A Draft Part from a socio-economical report of Armenia), greenflies, caterpillar and Colorado potato beetle are the main pests in Hayanist. In the following table 2, the more detailed description of them is listed.

Table 2
Three main pests and related host

Pest	Host Plant
Greenflies (any of various species of Aphids)	Cucumber, eggplant, tomato, watermelon, cabbage, beans, peas, spinach, paprika, *et al*
Caterpillars (the larva of a butterfly, moth or sawfly, which has a segmented worm-like body, often hairy or conspicuously patterned, several pairs of legs and strong jaws)	Mainly caused damage on cruciferous vegetables including cabbage, lettuce, broccoli, cowl, cauliflower; white radish, et al; tomatoes, watermelon, cucumber, peas, pumpkin and spinach
Colorado Potato Beetle	Potato and related plants in genus *Solamum*; eggplant, pepper and tomato

3.1.1 Chemical pesticide control

At the beginning of this project, chemical control still needs to be used to improve the products of crops and vegetables. About specific pests related to Hayanist, some details of pesticides are described in the following paragraph.

Colorado potato beetles (CPB)

Continued insecticides application on CPB will improve the chance of them resistant to pesticides. Serious problems with insecticide resistant strains have been present in many part of North America. For the short term, it is reasonable or better to use some effective insecticides together with other methods to control CPB. Thus, for chemical control, if a particular insecticide is not working in the field, a switch to another class of chemicals might be helpful. Insecticides recommended for control of Colorado potato beetles, especially on potatoes are:

a. Organophosphates - Thimet, Imidan, Di-Syston, Monitor,
b. Carbamates - Vydate, Furadan, Sevin
c. Pyrethroids - Asana, Ambush, Pounce, Baythroid
d. Nicotinoids - Admire, Provado, Platinum
e. Other - Agri-Mek, Thiodan, Kryocide, SpinTor, Bt insecticides
f. Imidacloprid is a fairly new systemic and contact chemical that has shown dramatic control or even resistant CPB (Whitney, 2004).

Caterpillar and aphids

Many caterpillars and aphids are resistant to chemical insecticides. Repeatedly using one type of pesticides results easily in development of resistance. Therefore one should be very careful to use insecticides to control them. Whenever using pesticides, be sure to follow the directions and read the cautions found on the label. Most of the used pesticides are listed in table 3.

Table 3
Lists of effective pesticides against caterpillars and aphids

Insecticides	Signal Word	Target Pests
Dibrom (naled)	Danger	caterpillars
Dimethoate	Warning	aphids, leafhoppers, mites
Imidan (phosmet	Warning	caterpillars, sweetpotato weevil
Lorsban (chlorpyrifos)	Caution	caterpillars, soil pests
Orthene (acephate)	Caution	aphids, caterpillars
Larvin (thiodicarb)	Warning	caterpillars
Pyronyl (Pyrethrins	Caution	broad spectrum
Ambush (permethrin)	Warning	caterpillars, beetles, leafhoppers, thrips
Ammo (cypermethrin)	Caution	caterpillars, beetles, leafhoppers, thrips
Avaunt (indoxacarb)	Caution	caterpillars
Fulfill (pymetrozine)	Caution	aphids, whiteflies
Confirm (tebufenozide	Caution	caterpillars
Actara (thiamethoxam)	Caution	aphids, some beetles, potato leafhopper, stinkbugs, whiteflies
Admire (imidacloprid	Caution	aphids, some beetles, leafhoppers, whiteflies
Assail (acetamiprid)	Caution	aphids, Colorado potato beetle, whiteflies
Platinum (thiamethoxam)	Caution	aphids, some beetles, potato leafhopper, stinkbugs, whiteflies
Provado (imidacloprid)	Caution	aphids, some beetles, leafhoppers, whiteflies
SpinTor (spinosad)	Caution	caterpillars, some beetles and thrips

In practice, farmers can use pesticides when insects appear in damaging numbers. For Beans (snaps & limas): Do not exceed 7 applications of a registered insecticide. For Cabbage (not for brussels sprouts), Carrots, Greens or Leaf Crops (turnips, kale, spinach, or collards), Lettuce, Okra, Pea, Pepper (bell or hot), Potato, Strawberry, and Tomatoes: follow the label on a registered insecticide. For Cucurbits (cantaloupes, cucumber, squash, pumpkins, and watermelons): Treat when seedlings emerge. Treat when insects appear in damaging numbers. Repeat as needed. Use a registered insecticide (Webb & Stansly, 2004).

3.1.2 Cultural control - crop rotation

- **What is crop rotation**

Crop rotation is a component of cultural control. The greatest benefit of a good crop rotation is increasing the yields. A well-planned crop rotation will help insect and disease control and will aid in maintaining or improving soil structure and organic matter levels. Using variety of crops can reduce weed pressures, spread the workload, protect against soil erosion and reduce risk. Legume crops in the rotation have become more valuable because these crops reduced the cost of nitrogen fertilizers. Research and experience have proven that a good crop rotation will provide more consistent yields, build soil structure and increase profit potential.

- **Why we use crop rotation**

There are three main advantages about crop rotation and all of them are described in the following paragraph.

Soil Depletion: Each crop uses different types and amounts of minerals from the soil. If the same crop is planted every year in the same place, after several years the soil is depleted of the minerals essential for plant growth and health. In the other hand, a different crop will sometimes return the missing minerals to the soil as the plant dies and decomposes, or is turned into the soil.

Insect Control: Insects over winter in the soil of the field. They enter the leaves and vines of the plants. When the farmers plow or turn the garden over, some of those insects find a very cozy home for the winter inside decaying plant matter under the soil. Those grateful insects re-awaken in the spring hungry to re-infest the new crop.

Disease Prevention: Just like insects, plant diseases can also over winter in plant leaves and vines under the soil. So the farmers can help guard against this by removing and destroying any diseased plants.

Crop rotation can break the cycles of pest and disease problems that build up in soils planted repeatedly to the same crop. It is better to plan the rotation because none of the two crops subject to similar diseases follow one another within the disease's incubation period in the same field. The same principle holds for insect pests: crop rotation makes it harder for emerging insects to find their preferred food for each spring.

How to rotate the crops

It is better to rotate the field on a three or four years cycle and each crop should be rotated every year, thus each crop can not grow in the same field in the three or four years cycle. They should be rotated every year. For example, corn which is planted this year is not planted in the same field for the next two or three years. Some agricultural department recommends some plants, such as pumpkins, should not be planted in the same field for up to seven years (Shepherd, 1992).

It is important to balance the nutrient demands that each crop makes on the soil, therefore it is better to divide the crops into the following four types, for four different seasonal rotations:
Leafy plant: Thrive on nitrogen; examples include lettuce, salad greens, chicory, spinach, broccoli, Brussels sprouts, cabbage, cauliflower, kale and kohlrabi.

Fruit plant: Need phosphorus; examples include squashes, cucumbers, melons, pumpkins, tomatoes, peppers, and eggplants.

Root plant: Love potassium; examples include onions, shallots, garlic, scallions, leeks, carrots, beets, turnips, and radishes.

Soil builders and cleaner plant: Legumes are excellent for the soil because they store nitrogen from the air and release it into the soil; examples of cleaners include corn and potatoes, examples of builders include beans and peas.

The first season of planting could be devoted to leafy plants, the next season to fruits, followed by the root plants and then legumes. The normal used rotated crops are listed in table 4.

Table 4
Normal used of rotated crops

Cultivitaed Crops	Rotated Crops
squash	melons, cucumber, and pumpkins
mustard	broccoli, brussels sprouts, cabbage, cauliflower, kohlrabi, kale, mustard
tomato	eggplants, peppers, and potatoes
beet:	spinach and chard
legumes	beans and peas
onion	leeks, scallions, garlic, and shallots
carrot	dill, parsnips, and parsley

- **Specific examples for different pests**

Colorado potato beetle (CPB)

Crop Rotation: The CPB over winters in the soil as adult beetle and in the spring these adults emerge to find the host plants especially potatoes and eggplants. Its flight activity below 22 degree and normally potato can grow lower than this temperature. Rotational potatoes that are away from the previous season's potato field can grow early and substantially before CPB's colonization through walking or flying. Several researches have proved rotation can reduce the insecticides application and maintain acceptable CPB control. In practical rotation, the non-host plants for example in home garden cucumber, cabbage, peas and pepper can be used. The distance between rotated potatoes or eggplants and non-host plants should be 0.3 Km (Johe & Sterrett, 1998).

Caterpillars

The normal symptom caused by caterpillars is on the leaves of the vegetables leaving many holes and making the vegetables inappropriate for sale in market. In a serious attack the whole plant might be defoliated leaving only the midrib of the plant. They have a very short life cycle; therefore outbreak of damage is very fast. There are very significant variations of culture control methods toward different species. Crop rotation is suitable for most of them especially on normally occasional Diamondback Moth. Expect that, field disking and destruction of crop residues also are important for control of all caterpillars because this can reduce their migration into nearby crops. For some species that develop well on several weeds in the Amaranth group, thus weed control on ditch banks surrounding fields can help reduce populations of these caterpillars before they invade fields for example beet armyworms (Nuessly & Webb, 2004).

Aphids

Aphids are very prolific insect. Normally female aphids (stem mothers) give birth to live offspring (3-10/ day) that start to feed immediately. Within a week, this offspring will be ready to reproduce. Aphids can have two forms: winged or wingless. Several species attack various crops causing stunting, and leaf curling. The most effective culture control methods include before planting vegetables removing weeds surrounding the field, checking incoming plant material, disposing of plant debris, and avoid growing ornamentals in vegetable production area (source; IPM for the Home Vegetable Garden).

3.1.3 Cultural control - trap cropping

What is trap cropping

Trap cropping is the planting of a trap crop to protect the main cash crop from a certain pest or several pests. The trap crop can be from the same or different family group, than that of the main crop, as long as it is more attractive to the pest. There are two types of planting the trap crops; perimeter trap cropping and row intercropping. Perimeter trap cropping (border trap cropping) is the planting of trap crop completely surrounding the main cash crop. It prevents a pest attack that comes from all sides of the field. It works best on pests that are found near the borderline of the farm. Row intercropping is the planting of the trap crop in alternating rows within the main crop.

The principle of trap cropping rests on the fact that virtually all pests show a distinct preference to certain plant species, cultivars, or a certain crop stage. Manipulations of the stands in time and space so that attractive host plants are offered at the critical time in the pests and the crop’s phenology lead to the concentration of the pests at the desired site, the trap crop. Techniques of manipulation range from establishing an early or a late trap crop of the same cultivar as main crop to panting a completely different plant species (Hokkanen, 1991).

Farmers are motivated to utilize trap cropping because of the difficulties in coping with the pest situation in other ways. Sometimes the cost of chemical pesticides and the number of treatments required is high, therefore more economical ways have to developed (Swezey, 1988). Additionally, the pest have often evolved resistance to commonly used pesticides (Swezey, 1987), which requires some alternative control strategies. In some cases, no effective chemical pesticides are available, as for the treatment of cauliflower just before harvest.

Besides its potential role in improving the environmental soundness and overall performance of conventional agriculture, trap cropping techniques may have special importance to subsistence farming in the developing countries such as China and India. Additionally, the increasing sector of organic farming also could exploit this strategy of pest control (Hokkanen, 1991). Another function of trap crops is their use for attracting natural enemies of pest insects to the fields and concentrating them there to enhance naturally occurring biological control.

- **How to use trap cropping**

1. Make a farming plan which will guide the farmers on where the trap crops are to be sown or planted.

2. Learn to know and identify the pests.

3. Select a trap crop which is more attractive to the pest than the main crop and then ask for assistance from your local agriculture technological station (if it is possible).

4. Monitor your plants regularly.

5. Control the pests that are found in the trap crop immediately. Prune or remove the trap crops once the pest population is high, otherwise they will serve as the breeding ground and the pests will attack the rest of your farm.

6. Be ready to sacrifice your trap crop as an early crop and destroy them once pest infestation is high.

7. Keep farm records always.

This is the example for the main pest Colorado potato beetle (CPB) in Hayanist. Trap crops planted 5–10 days before main crops (sized 5% of main crop area) were recommended for CPB especially on *L. decemlineata* management and 2–5 ha of trap crop provided sufficient protection for 200–500 ha of main economic crop in Russia. The attractiveness of trap crop plantings to insect pests might be further enhanced by application of attractive semi chemicals, such as insect pheromones or plant kairomones. Subsequent insecticide application to a trap crop after colonization may decrease the frequency of application, spray area, total volume and associated management costs for a crop system at the same time as maintaining adequate pest control (Martel, 2005).

Trap crop examples

Table 5
Examples of trap cropping practices

Main crop	Trap crop	Method of planting	Pest controlled
Corn	Beans and other legumes	Row intercrop	Leafhopper Leaf beetles Stalk borer Fall armyworm
	Napier grass (ICIPE, 2003)	Intercrop Border crop	Stemborer
	Soybean	Row intercrop	Heliotis sp.
	Sudan grass (ICIPE, 2003)	Intercrop Border crop	Stemborer
	Vertiver grass (van de Berg, Undated)	Perimeter crop	Corn stalk borer

Cabbage	Chinese cabbage, mustard, and radish (Facknath, 1997; Muniappan; Lali, 1997)	Planted in every 15 rows of cabbage	Cabbage webworm Flea hopper Mustard aphid
	Collards (Boucher; Durgy, 2003)	Border crop	Diamondback moth
	Indian mustard (Cornell University, 1995)	Strip intercrop in between cabbage plots	Cabbage head caterpillar
	Nasturtium (Ellis; Bradley, 1996)	Row intercrop	Aphids Flea beetle Cucumber beetle Squash vine borer
	Radish (Ellis; Bradley, 1996)	Row intercrop	Flea beetle Root maggot
	Tomato (Makumbi, 1996)	Intercrop (Tomato is planted 2 weeks ahead at the plots' borders)	Diamondback moth
Tomato	Dill and lovage (Ellis; Bradley, 1996)	Row intercrop	Tomato hornworm
Potato	Horse radish (DA, Philippines, 1997)	Intercrop	Colorado potato beetle
	Tansy (DA, Philippines, 1997)	Intercrop	Colorado potato beetle
Carrot	Medic, Medicago litoralis (Miles, C.; et al., 1996)	Strip intercrop in between carrot plots	Carrot root fly
Carrot	Onion and garlic	Border crops or barrier crops in between plots	Carrot root fly Thrips
Soybean	Green beans (Ellis; Bradley, 1996)	Row intercrop	Mexican bean beetle
	Rye (OIKOS, 2003)	Row intercrop	Corn seedling maggot
	Sesbania (Naito, 2001)	Row intercrop at a distance of 15 m apart	Stink bug
	Sickle pod (OIKOS, 2003)	Strip intercrop	Velvet bean caterpillar Green stink bug
Cotton	Alfalfa (Meyer, 2003)	Strip intercrop	Lygus bug
	Castor plant (Hasse, 1986; 1987)	Border crop	Heliotis sp.
	Chick pea (Grundy; Short, 2003)	Block trap crop at 20 plants/ sq m (Brown, 2002)	Heliotis sp.
	Corn (Hasse, 1986; 1987)	Row intercrop, planted in	Heliotis sp.

		every 20 rows of cotton or every 10-15 m	
	Cowpea (CIKS, 2000)	Row intercrop in every 5 rows of cotton	Heliotis sp.
	Okra (Hasse, 1986; 1987)	Border crop	Flower cotton weevil
	Sunflower (CIKS, 2000)	Row intercrop in every 5 rows of cotton	Heliotis sp.
	Tobacco (Hasse, 1986; 1987)	Row intercrop, planted in every 20 rows of cotton	Heliotis sp.

3.1.4 Cultural control - intercropping

- **What is intercropping**

Intercropping is the cultivation of two or more crops simultaneously on the same field. It also means the growing of two or more crops on the same field with the planting of the second crop after the first one has completed its development. The rationale behind intercropping is that the different crops planted are unlikely to share the same insect pests and diseased-causing pathogens and to conserve the soil.

- **The types of intercropping**

Mixed cropping is the cultivation of two or more crops simultaneously on the same field without a row arrangement.

Relay cropping is the growing of two or more crops on the same field with the planting of the second crop after the first one has completed its development.

Strip cropping is the cultivation of different crops in alternate strips of uniform width and on the same field. It has two types: contour strip cropping and field strip cropping. Contour strip cropping follows a layout of a definite rotational sequence and the tillage is held closely to the exact contour of the field. Field strip cropping has strips with uniform width that follows across the general slope of the land (ICIPE, 2003).

Row intercropping is the cultivation of two or more crops simultaneously on the same field with a row arrangement.

- **The advantages**

----- Reduce the insect pest populations because of the diversity of the crops grown. When other crops are present in the field, the insect pests are confused and they need more time to look for their favorite plants.

----- Reduce the plant diseases. The distance between plants of the same species is increased because other crops (belonging to a different family group) are planted in between.

----- Reduce hillside erosion and protects topsoil, especially the contour strip cropping. Attract more beneficial insects, especially when flowering crops are included the cropping system.

----- Minimize labor cost on the control of weeds. A mixture of various crops gives often a better coverage of the soil leaving less space for the development of weeds.

----- Utilize the farm area more efficiently.

----- Result in potential increase for total production and farm profitability than when the same crops are grown separately.

----- Provide two or more different food crops for the farm family in one cropping season.

- **Examples of intercrop systems**

Traditional corn-bean-squash mixed intercrops

A common intercrop of corn, beans, and squash is traditionally grown all over the world. Grown together, these three crops optimize available resources. The corn towers high over the other two crops while the beans climb up the corn stalks. The squash plants sprawl along the ground, capturing light that filters down through the canopy and shading the ground. The shading discourages weeds from growing. This mixture was compared to the individual crops grown separately in a study near Tabasco, Mexico (Amador, 1980). In the study, corn yields were considerably higher in the mixture than in a pure stand planted at optimum densities. Bean and squash yields suffered considerable yield reductions when grown in mixture. In this example if corn was the most important crop, it was beneficial to grow it in mixture with squash and beans. The beans and squash were just a bonus. The leaf are rate (LER) for the whole mixture was considerably higher (1.6) than any of the pure stands.

Corn and soybean mixed intercrops

Canadian researchers (Martin, 1987) worked with several corn-soybean intercrop seeding rates to determine their economic advantages as silage. Pure stands of corn and soybeans were grown for comparison at 24,000 corn seed per acre and 200,000 soybean seed per acre. Results showed that intercrops were more cost effective than pure stands over both years the study was conducted. The study featured five experimental intercrop seeding rates with two planting arrangements (alternate and within the row). The researchers concluded that a planting rate of 16,000 corn seed per acre (67% of the full corn rate) with 135,000 soybean seed per acre (67% of the full bean rate) planted within the same rows along with 53 lbs. of N/acre gave the highest economic returns. This mixture gave an leaf area rate (LER) of 1.14 over pure stand yields. The crude protein level of the intercrop silage was considerably higher than that of pure corn silage. A slightly higher yield was achieved from full stands of both corn and beans in alternate rows (LER=1.23) but the cost of production was higher, thus offsetting the improved yields.

Corn and sorghum mixed intercrops

Research on intercropping forage sorghum into silage corn is an example of corn and sorghum mixed intercrops. First, they planted the corn at 28,000 seed per acre, then went back over the field with a drill with enough drop tubes closed off to plant 8 pounds of sorghum on 32-inch rows in between the corn. They also planted two different maturities of corn, a 95-day and a 75-day, to even out the silage moisture content. They harvested a mix of corn in hard dent and soft dent, and sorghum in the milk stage (reviewed in Amador, 1980).

Strip cropping corn/soybeans/small grains

American farmer Tod Intermill plants alternating strips of corn, soybeans, and spring wheat on his farm (Anon, 1987). The strips are six rows wide in a ridge-till system. All the crop plantings are adapted to existing equipment widths. Regular herbicide treatments can be applied using a ground sprayer of strip width. Even the wheat is drilled on ridges, using a drill with individual depth gauges on each opener. Intermill orients his rows east and west to minimize shading effects of taller crops like corn. The crops are planted in a wheat-corn-soybean pattern with soybeans on the north side of the corn. This arrangement reduces the effect of corn shading often associated with a straight corn-soybean pattern, since the wheat is mature before the corn has a chance to shade it. Corn gains the greatest benefit from the additional sunlight interception on the outside rows of the corn strip.

3.1.5 Biological control - natural enemy

In order to reduce the amount of pesticides application and their impact on human health and environment, biological control appear to be important position in pest management. In addition, many pests have developed resistance to many pesticides and to overcome this and decrease the resistance of pests, biological control should be applied more widely.

Biological control is a component of the integrated pest management strategy. It is different from chemical, cultural, and mechanical controls in that it requires maintenance of some level of food supply (e.g., pest) in order for the bio control agent to survive and flourish. Therefore, biological control alone is not a method to kill the pest completely. Biological control is defined as the reduction of pest populations by natural enemies.

Biological control agents of natural enemy

Natural enemies of insect pests, known as biological control agents, include predators, parasitoids, and pathogens.

Parasitoids. This wasp is laying its egg inside an aphid where its young will develop.

Parasitoid immature develop on or inside a host, killing the host when they are mature. They emerge as adults and continue the cycle.

Predators. Lady beetles are well-known examples of predatory insects. A predator consumes much prey during its lifetime. The predators listed in this guide feed on insects and mites.

Pathogens. This nematode is just one example of a pathogen which may kill its host. Other pathogens include bacteria, viruses, fungi and protozoa. This section also includes antagonists which control plant diseases (Li, 2005).

- **Approaches**

There are three general approaches to biological control: importation, augmentation and conservation of natural enemies. Each of these techniques can be used either alone or combined with others to build a biological control program.

Importation of natural enemies, sometimes referred to as classical biological control, is used when an outside pest is the target of the biocontrol program. Pests are constantly being imported into countries where they are not native. Many of these introductions do not result in establishment or if they do, the organism may not become pests. However, it is not uncommon for some of these introduced organisms to become pests, due to a lack of natural enemies to suppress their populations. In these cases, importation of natural enemies can be highly effective.

Once the country of origin of the pest is determined, exploration in the native region can be conducted to search for promising natural enemies. If such enemies are identified, they may be evaluated for potential impact on the pest organism in the native country or alternatively imported into the new country for further study (Caltagirone, 1981).

Augmentation is the direct way of natural enemies to increase their effectiveness. This can be accomplished by one or both two general methods: mass production and periodic colonization or genetic enhancement of natural enemies. The most common use of these approaches is the first, in which natural enemies are produced in insectaries, then released inoculatively. Augmentation is used where populations of a natural enemy are not present or cannot respond quickly enough to the pest population. Therefore, augmentation usually does not provide permanent suppression of pests, as may occur with importation or conservation methods.

Conservation of natural enemies is a critical component in the biological control effort. This involves identifying the factors which may limit the effectiveness of a particular natural enemy and modifying them to increase the effectiveness of the beneficial species. Generally, conservation of natural enemies involves either reducing factors which interfere with natural enemies or providing resources that natural enemies need in their environment (Douglas, 1996).

- **Specific examples for related pests**

Colorado potato beetle (CPB)

<u>Predator and Parasites</u>: There are three target stages to control the CPB using natural enemy. One is larvae of CPB, another is adult and last one is eggs of CPB. For the larvae, because it stays in the soil some ground beetles for example *Lebia* and *Pterostichus spp*. and two-spotted stink bug *Perillus bioculatus* (Fabricius) and the spotted lady beetle *Coleomegilla maculata* (DeGeer) are useful to consume the larvae of CPB. For the adult stage, tachinid fly *Myiopharus doryphorae* parasite the adult of CPB and the bacteria of *Bacillus thuringiensis* (Berliner) can parasite the CPB. For the eggs of CPB, tiny wasps are Parasitoid in the families *Eulophidae, Scelionidae, Trichogrammatidae,* and *Mymaridae*. But until now none of these natural controls are effective in the practical field. However toxins from strains of the bacterium have been registered for commercial use and have good potential for utilization because of their specificity to Colorado potato beetle (Lucas, 2004).

Caterpillars

<u>Predator</u>: the normal predators of caterpillar include spider, ground beetles and lacewings. Spider can eat the most of soft caterpillar. Ground beetles and lacewings normally eat the smaller and softer caterpillar. In practice, farmers should avoid using (broad-spectrum these pesticides and make permanent plants around the field to provide hiding place for the adult beetles. About lacewings moisture is good for the larvae growth and flowering plants around the field benefit to their survival. They can be bought from many companies of U.S. and Europe. For spiders, a lot of organic mulch can increase the number of spiders because spiders can hide in the layer of mulch and they find protection from sun and rain and also avoid using broad-spectrum insecticides.

<u>Parasitoid</u>: most parasitoids are small wasps that they lay their eggs inside a caterpillar in the families, *Trichogramma, Ichneumonidae, Braconidae, Eulophidae,* and *Chalcididae*. A few parasites are hairy flies in the family *Tachinidae*. For the actual application of these two parasitoids, Avoid using broad-spectrum insecticides for any insect pests are important (Michael & Koen, 2001).

<u>Parasites</u>: there are two mainly used organisms including fungi and virus. Several species of fungi can cause the disease of caterpillar for example *Nomuraea rileyi* and *Zoophthora radicans.* Both of them have been confirmed that they can cause serious disease of caterpillar and have the potential to be used commercially in the future. In addition there are two main types of virus that can cause disease of caterpillar. They are *Nuclear polyhedrosis* virus (NPV) and Granulosis virus. First one has been used to biological agents in the practical field and second only has been found in several caterpillar species. In pratice, farmers should be careful of using fungicides and herbicides because they can inhibit or kill these fungi (Michael & Koen, 2001).

Aphids

<u>Predator</u>: Commercially used predators are lady beetles, lacewings and predatory midge. But there are still more two potential ones and they are ants and hover fly. Lady beetles (Hippodamia convergens) feed on aphids. However broad-spectrum insecticides can kill them, farmers should avoid using these pesticides. Also because lady beetles feed on pollen

and like shelter, it is better to plant flowering plant or weeds near the filed or some plants can be shelter around the field. Lacewings (*Chrysoperla rufilabris*) are sold as eggs or larvae. The larvae are greedy predators known as “aphid lions”. Moisture is good for the larvae growth and flowering plants around the field benefit to their survival. They can be bought from many companies of U.S. and Europe. Predatory midge (*Aphidoletes aphidimyza*)’s adult has the function to lay eggs near aphid colonies and the orange larva feeds on aphids (Michael & Koen, 2001).

Parasitoids: there are very specific species of parasitoid for aphid biological control. Three of them are widely used including *Aphidius colemani*, *Aphelinus abdominalis* and *Aphidius ervi*. These three have different targets. The first one is used to control green peach aphid and melon aphids. It lays eggs in the aphid and the larvae cause damage to aphids. Second is used to control potato aphids. Third one is used to control larger aphid species such as potato aphid and glasshouse potato aphid. The main advantage to using them is that the female adult will parasitize for several weeks and it will also feed on the aphids and disadvantage is they are sensitive to pesticides. In practice, planting flower plants and providing water source can make them live longer and farmers can spread them through redistribute leaves containing aphid mummies (HortReport, 2001).

Parasites: now there are only three parasite organisms from fungi for the aphid’s parasite. One is *Metarhizium* species and it can be an important control agent of aphids, but not commercial. *Zoophthora radicans* has been found infecting cabbage aphids and has the potential future application. Only *Verticillium lecanii* is used commercially in Europe against aphids, especially in greenhouse. In practice, the noticed thing is same to the caterpillar biological control (Finch, 2001).

3.1.6 Biological control - natural pesticides

- **What is natural pesticide**

Natural pesticides are extracted from plant materials and they are developed as the alternative for synthetic pesticides (Relf, 1997). They are harmless comparing to synthetic pesticides partly since they break down faster. However most natural pesticides are extremely toxic, protective clothing is still necessary since they also give acute effects and chronic effects to human. The prevention of pesticide surplus to environment also needs attention since it have the side effect on other organism as well, especially cold-blooded animals.

- **Available types of natural pesticides**

Several types of pesticides are now available, e.g. Pyrethrum, Rotenone, Ryania, Sabadilla, Nicotine, neem product.

Pyrethrum is derived from Dalmatian Chrysanthemums (*Chrysanthemum cinerariaefolium*) (Duval, 1993). The active compound is called Pyrethrins. It has effect against pickleworms, aphids, leafhoppers, spider mites, harlequin bugs, cabbageworms, Mexican bean beetles, flea beetles, flies, squash bugs. The application of pyrethrum can be done through dusting, spraying, and additive. Via dusting, dried *Chrysanthemum* flowers are grinded and apply on plants. It can also mix with lime, talc, gypsum, or diatomaceous earth to enhance effectiveness. For spraying, and additive, extraction of active compound from flower is needed. Pyrethrin is extremely toxic to aquatic life, such as bluegill and lake trout while. it is slightly toxic to bird species, such as mallards.

Rotenone is derived the roots of several tropical and subtropical plant species belonging to the genus *Lonchocarpus* or *Derris*. The active compound is called rotenoids. Colorado potato beetle, Mexican bean beetle, Japanese beetle, flea beetles, fleas, cucumber beetles, spittlebugs, aphids, potato beetles, mites, carpenter ants, cabbage worms, and loopers. The formulations of Rotenone are in dispersible powder, emulsifiable concentrate, and wettable powder (Source: PAN). Rotenone is believed to be moderately toxic to humans with an oral lethal dose estimated from 300 to 500 mg/kg. WHO classify rotenone as a moderately hazardous, Class II. It has side effects to fish, rabbit, pig and rat as report so far.

Ryania is made from the ground stems of *Ryania speciosa* from tropical America. The active compound is an alkaloid called ryanodine (source: Extoxnet). The target pests of ryania are codling moths, corn earworm, oriental fruit moth, potato aphids, onion, thrips, and corn earworms. Ryania is labeled with the 'caution signal' word since it has a very low toxicity to mammals. However, the pure ryanodine alkaloid is very toxic. Its toxicity is about 500 to 700 times more than the crude powder.The estimated lowest lethal dose for man is 143 mg/kg. Ryania is moderately toxic to birds and wildfowl and fish.

Sabadilla is derived from the seeds of the sabadilla lily (*Schoenocaulon officinale*) (Pottorff, 2005). Veratrine is the active compound of Sabadilla. The target pests of this compound are armyworms, harlequin bugs, stink bugs, cucumber beetles, leafhoppers, cabbage loopers, blister beetles. It is considered among the least toxic of botanical insecticides and breaks down rapidly in sunlight. Sabadilla is classified as slightly toxic (LD50 of 4,000 to 5,000 mg/kg); therefore it is labeled as caution. Sabadilla dust give irritation to eyes and produce sneezing if inhaled.

Neem is derived from the seeds of the neem tree, a native of India (Pottorff, 2005). The active compounds from neem tree are azadirachtin and salannin. The mixture of neem extract has insecticidal activity, controling gypsy moths, leafminers, sweet potato whiteflies, western flower thrips, loopers, caterpillars and mealy bugs. Moreover other unknown compounds in neem mixture also have fungicidal activity. This natural pesticide has low mammalian toxicity with an LD50 of 5,000 mg/kg.

Nicotine is a tobacco extract highly toxic to warm-blooded animals (English, 1994). The insecticide usually is diluted in water and applied as a spray. Dusts can irritate the skin and are not normally available for garden use. Nicotine is targeted for piercing-sucking insects such as aphids, whiteflies, leafhoppers and thrips. Nicotine is more effective when applied during warm weather. It degrades quickly, so can be used on many food plants nearing harvest (English, 1994).

Table 6
Natural pesticides and their target pests

Name	Active compound	Source	Target pest	Toxicity
Pyrethrum	Pyrethrins	*Dalmatian Chrysanthemums*	pickleworms, aphids, leafhoppers, spider mites, harlequin bugs, cabbageworms, Mexican bean beetles, flea beetles, flies, squash bugs.	extremely toxic to aquatic life
Rotenone	rotenoids	Plant roots belonging to the genus *Lonchocarpus* or *Derris*.	Colorado potato beetle, Mexican bean beetle, Japanese beetle, flea beetles, fleas, cucumber beetles, spittlebugs, aphids, potato beetles, mites, carpenter ants, cabbage worms, and loopers.	Oral lethal dose for man is from 300 to 500 mg/kg
Ryania	ryanodine	stems of *Ryania speciosa*	codling moths, corn earworm, oriental fruit moth, potato aphids, onion, thrips, and corn earworms.	lethal dose for man is 143 mg/kg.
Sabadilla	Veratrine	seeds of the sabadilla lily (*Schoenocaulon officinale*)	armyworms, harlequin bugs, stink bugs, cucumber beetles, leafhoppers, cabbage loopers, blister beetles.	LD50 for man is 4,000 to 5,000 mg/kg
Nicotine	Nicotine	Tobacco (*Nicotiana tabacum* L.)	piercing-sucking insects such as aphids, whiteflies, leafhoppers and thrips.	Oral LD50 is 50 mg/Kg

Colorado potato beetle

One potential botanical insecticide-piperine, extract from the piper, has been demonstrated that it can knock down the larvae and adult of CPB (Scott, *et al* 2003).
Another one is neem whose active ingredient azadirachtin and that is extracted from neem tree seeds. It can be used to control CPB at the eggs hatch and immature stages (Henn & Weinzierl, 1989).

Caterpillars

There are types of normally used botanical insecticides. One is sabadilla derived from seeds of the South American lily (*Schoenocaulan officinale*) and is sold under the trade names of “Red Dog” and “Natural Guard. It is labeled to control vegetable pests. It can cause loss of nerve function, paralysis and death. Synergists also are added to sabadilla to increase insect mortality and it has an Oral LD50 of 4,000 mg/kg, vomiting etc. Sabadilla is toxic to humans and is extremely toxic to honeybees. It breaks down rapidly in air and sunlight with little residual activity (Jefferson, 2005). Another one is Azadirachtin or called Neem that is insect growth regulator derived from kernels of the neem tree. It can block the insect's production of hormones, and interrupts the moulting process, preventing the insect from completing its life cycle. This compound is no harmful to beneficial insects and can control caterpillars (Henn & Weinzierl, 1989).

Microbial insecticides: *Bacillus thuringiensis* (Bt) only target caterpillars but not harm other beneficial organisms. The most widely used Bt insecticides are formulated from the bacteria *Bacillus thuringiensis var. kurstaki*. This isolate is toxic only to the larvae of butterflies and moths. Insects may die quickly or may stop feeding within 2 to 3 days.

Aphids

Until now available botanical insecticides that can control aphids are Rotenone and Pyrethrum or Pyrethrins. Rotenone is derived from the roots of Lonchocarpus sp. (Cube roots) grown in South America. It can inhibit the cellular respiration in nerve and muscle cells causing rapid cessation of feeding. Rotenone has an Oral LD50 ranges from 60 mg/kg to 1500 mg/kg depending on the carrier. It is extremely toxic to fish. It is useful against leaf feeders including aphids and can degrade rapidly in air and sunlight without some residual effect.

The source of Pyrethrum and Pyrethrins is powdered and produced form dried flower heads of the pyrethrum daisy that is grown mostly in Kenya and Ecuador. It can disrupt nerve function and are labeled to control ants, aphids, roaches, fleas, and ticks. They degrade rapidly, leaving little or no residual activity. In practice, farmers should avoid mixing a pyrethrin compound with soap solutions as soap (Henn & Weinzierl, 1989).

3.2 Organic Agriculture

3.2.1 Introduction and objective

Organic agriculture is the style farming concerning about sustainability. The aim of the system is to promote the health of agro ecosystem including biodiversity, biological cycles and soil quality while the off-farm input is reduced. The farming system tends to adapt itself to the environment than controlling it. Therefore the agricultural products are the results of harmonization of the nature. These can be achieved by the employment of cultural, biological and mechanical practices as opposed to synthetic materials (van Bruggen, 2003; PAN 2004).

Organic farming system is considered as the real alternative while IPM is low-risked farming. After the use of pesticide in Hayanist has reduced due to IPM application, the organic farming can be applied more easily.

Objectives of organic agriculture

- to produce high nutritional and quality food in sufficient quantities
- to harmonize life with natural systems and cycles

- to enhance biological cycles within the farming system, including microorganisms, soil flora and fauna and plants and animals
- to maintain and increase long term soil fertility
- to conserve soil and water
- to enhance the use of renewable resources in locally agricultural systems
- to promote agricultural activities within a closed system regarding to organic matter and nutrient elements
- to promote recycling of materials and substances either on the farm or elsewhere
- to minimize all forms of pollution that may result from agricultural practice
- to maintain the genetic diversity of the agricultural system and its surroundings, including the protection of plant and wildlife habitats

3.2.2 Elements that can be done prior to or along with IPM (the transition period)

These elements need long period of time to achieve. Although they are part of organic agriculture, they do not interfere with the process of IPM.

Promotion of usage of renewable sources and recycling of on-farm and off-farm materials: This stage, the separation of garbage into glass, plastic, organic waste, and toxic waste can help villagers use the resource wisely and also prevent toxic waste contaminating to environment. Organic waste can be used as energy source (Biogas) as well as soil nutrient. This point can be done together with the ECOSAN project of WECF. In addition, the promotion of on-farm and off-farm recycling is not only for waste, but it also includes all other elements such as seeds and other agricultural equipments. The villagers together with organization (such as WECF) can construct the exchanging service. This office helps to collect all of the share agricultural equipments. The members of the service can pay a certain member fee in order to use the equipments. The apparatus include e.g. personal protective clothing, pesticides, etc. In sharing of pesticides, officers can control kinds of pesticides, and can give the essential information regarding to a particular pesticide to a renter. This reduces risk for villagers in misusing pesticides. Villagers will not have left over pesticides. So it reduces the potential of pesticide contamination into environment. Moreover, they do not have to keep pesticide in their house. This reduces risk in pesticide up taking. Nevertheless, it should be noted that providing pesticides is done in the very early stage. In the late stage of IPM and the beginning of organic agriculture (element after IPM), the pesticide using will be prohibited. By sharing service, villagers can reach the expensive and effective equipments. Thus their life can be safer and easier.

Maintenance and improvement of soil quality: Soil quality is the heart of organic agriculture. The improvement of soil quality can be done in short term through the reduction of pesticide use by following the short term solution of this guide line. For long term improvement, adding of organic material is the solution to improve available nutrient in soil. Three types of organic matters that are usually used in organic farm are composts, manures, and living mulches (van Bruggen, 2003). Compost comes from organic matter that passes through transforming process by soil organisms. Compost recipe can be viewed in appendix 1. Soil organism transform nutrient in organic matter in to ready to use form for the crop. Organic materials that can be used are in wide range e.g. plants (either dry or fresh), manure, waste from household. Farmer also can applied fresh animal manure to increase phosphorus level in soil.

<u>General tillage decision:</u> Disking and harrowing is the tillage operation done in conventional farming. In this way of tillage, it turns the surface of soil deeply (20-30cm) to expose soil lower layer to the sun or other management such as fumigating. Therefore soil is sterile for fine seedbed. Nevertheless, in the long run, it gives rise to changes in soil structure such as soil compaction, crush formation and erosion. As a result, soil losses fertility and structure. In this place ‘ridge tillage’ is recommended (Picture 1). In the ridge tillage, the permanent seedbed is used and the tillage is done only on top of the bed. It can be described as (van Bruggen 2003):

- The planter tills 5-10 cm of soil in a 15-cm band on top of the ridges.
- Seeds are planted on top of the ridges
- Soil from the ridge is mixed with crop residues between the ridges.
- Soils on the ridges are warmer than soil in the flat fields or soil between the ridges.
- Warm soil facilitates crop germination, which minimize weed emergence.
- Crop residues between the ridges also reduce soil erosion and increase moisture retention.

By this way seed can germinate easier that no-tillage and minimum tillage system and also it can conserve soil food web comparing to conventional tillage.

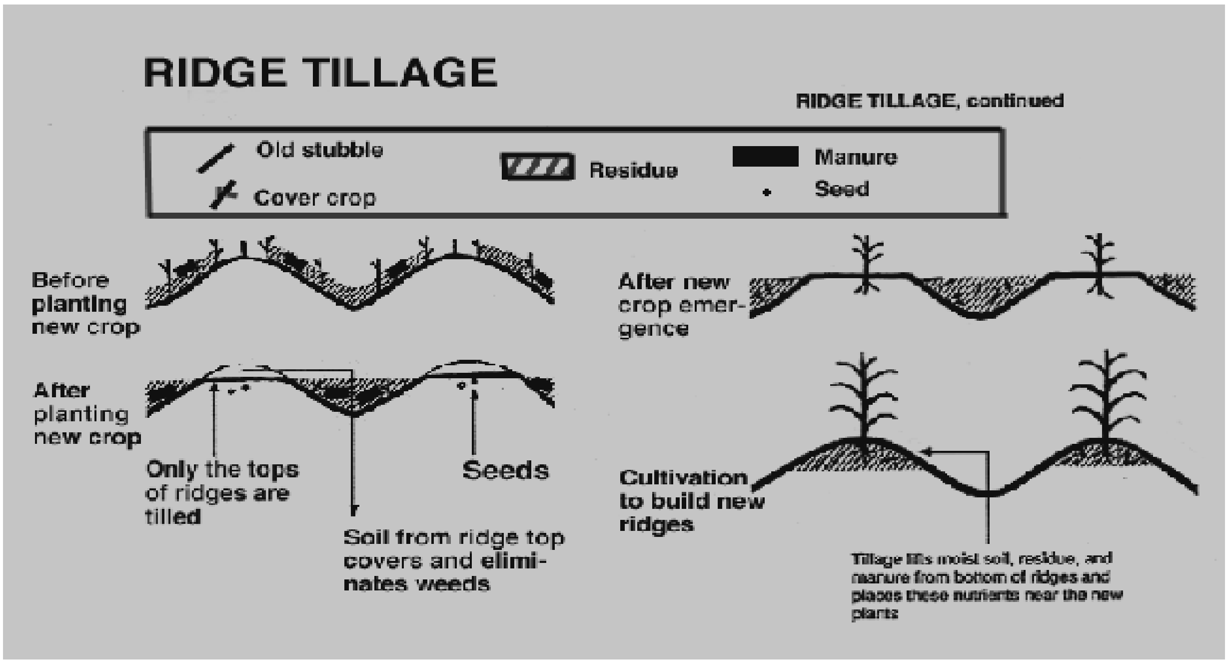

Figure 7. Ridge tillage (WSARE, 1995)

Conservation of genetic diversity: In organic agriculture, it tends to adapt the system to fit the environment instead of adapt the environment to fit the system. Therefore, the local plant cultivars and other local plants (nature plants) are conserved. Regarding to using of local plants, they are promoted to be used since they already have well adaptation to the local climate as well as local plant diseases. Nevertheless, if there are any cultivar choices fitting to the current pest available, farmers are also allowed to use. Concerning conservation of natural habitat, it can be beneficial to parasitoids and predators of pests. Therefore the more variety of genetic it is, the more balance the systems are. This is because all of the elements in the environment have mutual-interaction. By their own, they have mechanisms that prevent the out break of other species, i.e. pests and diseases.

3.2.3 Elements that can be done after IPM

Crop rotation: Crop rotation can not be done in the early stage due to the limitation of private land area. Since crop rotation need wide range of cultivated land to give the full effective in pest reduction (at least 1 hectare, personal communication with Dr. Wim Block), it is not suitable for small amount of land that individual farmers have. Crop rotation is very necessary in organic agriculture because

- It optimizes the use of nutrient
- It reduces mineral losses
- It maintain soil structure
- It prevent weed, pest and disease problems

To give the full effectiveness, the farmer cooperation has to be constructed in order to integrate the land into recommended area (1 hectare). Normally organic agriculture manages pest and disease through complex rotation. In stockless agriculture (no live stock production), the rotation has to include more leguminous crops to provide sufficient nitrogen supply. Otherwise, manure or compost can be used to full fill nitrogen need. Good crop rotation in this farming system is done in 4 to 6 years interval. This means that in a six year-cropped sequence, it should be 4 to 6 different kind of crops (1 crop/year).

The general suggestions of crop rotation are:

- Ensuring of sufficient alteration in time
    - Frequency of each crop less than 1 year in 6 years
    - Frequency of crop in the same family less than 1 in 3 years
    - Frequency of root crop less than 1 in 2 years
- Ensuring sufficient alteration in space
    - Move the crop in next year further away from the adjacent field that grew same crop in last year.

Crop divisions in to several groups are shown in tables below. Farmers can use these tables to assist the crop sequence decision.

Table 7
Crop division according to nitrogen demand

High	Medium	Low
Cabbage	Onion	Carrot
Potato	Grain	Pea
Leek	Leafy crop	Chicory
Celery	Maize	Glass-clover
		Barley

Source : Rossing (2003)

Table 8
Crop division according to ground coverage ability

Good	Medium	Poor
Grain	potato	Onion
Grass-clover	Pumpkin	Leek
Sugar beet	Maize	Red beet
Cabbage	Leafy crop	Carrot
	Beans (haricots)	Celery

Source : Rossing (2003)

Table 9
Crop division according to rooting

Good	Poor
Grains	Pumpkin
Grass-clover	Peas and bean
Leek	Leafy crop
Cabbage	Onion
Maize	Potato
Sugar beet	
Cabbage	
Carrot	

Source : Rossing (2003)

Chapter IV Conclusions and recommendations

4.1 Conclusions

According to our point of view, combination of the best methods from Integrated Pest Management (IPM) and organic agriculture is the best solution to improve the pesticide use in Hayanist and also provide steps toward sustainable agriculture in the future time. At the beginning, the methods of IPM are used to reduce pesticide gradually and at the same time educate villagers about good agricultural practices, proper pesticide application and also about protective clothing. After these steps, hopefully that the villagers understand the benefit of this farming system and also the environment conditions in Hayanist are healthier to start the organic agriculture farming system which replaced pesticide with pest and disease management through agricultural practices.
Although the combination of IPM and organic agriculture with all the steps are best to reduce pesticide use according to former study about Hayanist, there is a possibility that this alternatives might not fit to solve the problems in Hayanist due to lack of information such as details on environment conditions and natural resources which are important to find the best solution for Hayanist.

4.2 Recommendations

- To achieve sustainable agriculture needs cooperation and commitment from villagers therefore we encourage Hayanist villagers to have a farmer organization which help them exchange information and knowledge.

- We suggest the group AWHHE and the Agricultural University in Armenia that they can use some effective ways to help them give the guideline to the farmers.

  1. **Leaflet**. Hand out the leaflet directly to the farmers in Hayanist. This is an effective way to let the farmers know their problems and how to solve. By handing out the leaflet, we can also answer the questions from the villagers and know the real problems or situation right now in Hayanist, thus it is the closest way to contact the villagers.

  2. **Media**. Although the country is very poor, TV programs and the radio are still quite popular in Armenia. So we can use this easy and visible method to encourage and educate the people in front of the TV and radio. For example, in the TV or radio, it is possible to make a programme especially for telling farmers the problems and the solutions. Non-profit advertisement is also a good way to tell the farmers what they should do.

  3. **Farmer school**. In many developing countries in Asia and Africa, the farmer school is very popular, because farmers can learn lots of practical methods to deal with the problems in their fields. Therefore, this might also be suitable for Hayanist even Armenia. When the new technology developed by the scientists in the university, it can not be send to the farmers directly, on the other hand, when the farmers have some problems, they can not consult to the experts themselves. So

there should be a bridge between the village and the University. The farmer school is therefore the best option.

4. **The government** has a big responsibility to encourage the farmers to use a good way of planting. First, by making the law and legislation clear for using the pesticides. Second, by putting more funding to improve the pesticide use now in Hayanist. At last, the government should educate the villagers about the awareness on environment and health.

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Appendix I

Compost recipe:

Compost is compost of green material and brown materials. The green material, such as grass clippings, lettuce scraps, weeds, and other plant wastes, provide nitrogen source. Nitrogen source is important for the properly work of microorganisms. In addition to green material, brown material, such as dry leaves and cone piles, is needed. In the brown material, there are plenty of carbon source available. The carbon source provides energy for microorganisms who work in transforming the nutrient in the waste in to ready-to-use form.

- Wet the ground under the pile
- To help the pile get oxygen, some small twigs or leaves are placed at the bottom (brown stuff).
- Organic wastes is added (green stuff) and the pile should be somewhat as you are adding materials.
- Some soils are added to the pile. It contains the micro-organisms and worms that will help make the compost.

On the top of the pile, more leaves, hay, or very small twigs (brown stuff) are placed.
In a few days, pile should be very warm inside. Temperatures can reach 90 to 140 degrees within 4 to 5 days. Steam rising may rise from it. The pile should be mixed up and turn the pile every few days. It helps the micro organisms and worms to work on the entire pile. The pile should also has plenty of moisture without getting too wet. Compost piles will shrink as time goes by. This means the process is working. The composting process can take anywhere from 2 months to 2 years. When compost is ready to use, the dirt is powdery and dark. It will give woodsy and earthy smell.