ASSISTING SMALL-SCALE FARMERS IN ORGANIC AGRICULTURE: THE ROLE OF RURAL DEVELOPMENT ADMINISTRATION

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ABSTRACT

Organic Agriculture Division (OAD) was newly established to develop practical technologies for organic crop production at Korea’s National Institute of Agricultural Sciences (NAS), Rural Development Administration (RDA) in 2004. OAD has largely developed various organic farming technologies to support small-scale farmers (SSFs) and distribute these to the farmers. Research projects related to organic farming are selected through stakeholders’ committee based on research roadmap of RDA, policy demand, and on-site needs from farmers. Research main topics of OAD are as follows: development of organic farming system and crop protection technology; and assessment of environmental and ecological impacts of organic farming.

Firstly, we have been researching on organic soil and nutrient management including green manure crops, liquid fertilizers and composts. RDA Researchers confirmed that cultivation of hairy vetch could replace nitrogenous fertilizer in rice paddy field by sowing 6-9 kg of hairy vetch seed per 1,000m² in early October. Also nitrogenous, phosphorous and potassium liquid fertilizers were commonly made from rice bran and soybean flour, fish bone powder, molasses and yogurt, and charcoal-eluted solution, respectively and these are commonly used in Korea.

Secondly, the researches on crop disease and insect pest management by cultural, physical, and biological methods have been carried out. Various resistant varieties against potato late blight, pepper Phytophthora blight, etc. were selected and being cultivated in the farmhouse. Also cropping system for the control of potato late blight was developed by mix-cultivating potato with soybean and corn. The soil-borne disease, pepper Phytophthora blight, was suppressed by 43.9% through cultivating and soil-incorporating rye as green manure crop in high ridge cultivation compared to conventional pepper cultivation. Moreover, we selected an antagonistic bacterium Paenibacillus polymyxa AC-1 with high antifungal activity against the cucumber powdery mildew, rose powdery mildew and pepper Phytophthora blight, and a hyper-parasite, Ampelomyces quisqualis AQ94103, showing high penetrating activity against powdery mildew pathogens. These two antifungal agents were finally commercialized as microbial fungicides, ‘Topseed’ and ‘Q-Pect’, respectively.

We also researched on repellent plants, traps, and plant extracts for insect pest management. As a result, striped flea beetle, one of major pests of Chinese cabbage, could be effectively controlled by planting the repellent plants, basil and lemon balm around the Chinese cabbage field. Various traps such as sugar traps, light traps, pheromone traps, and sticky traps also were developed and commercially used in the farmhouses. Various plant extracts (pyrethroids, azadiractin, rotenone, and alkaloids, etc.) showing insecticidal activity against several insects were selected and are widely being used to control the insect pests in the farmhouses.

Thirdly, we provided the information about farmhouse-specific soil management based on the analysis of physico-chemical properties (pH, calcium and phosphorus contents) of organic farmland soil (paddy field, upland field, and orchard) to organic farmers.

Fourthly, we are trying to build organic network for international cooperation. In order to establish the base of organic agriculture, we have been organizing an organic guidance specialist training program jointly with International Federation of Organic Agriculture Movements (IFOAM) to continuously nurture outstanding organic experts. In addition, we have been developing the Asian Network for Sustainable Organic Farming Technology to share organic technologies, promote organic farming system, and establish the excellent model for an organic agricultural village.

Finally, the organic farming technologies developed by NAS have been continuously disseminated to organic farmers through publication of organic farming guide book/booklets, farmers’ education/training by central/local government, and uploading organic farming technologies on RDA website (www.nongsaro.go.kr).

Keywords: organic soil and nutrient management, organic crop protection, international cooperation, dissemination of organic technology, Korea
INTRODUCTION

Organic Agriculture is a production system that sustains the health of soils, ecosystems and people. It relies on ecological processes, biodiversity and cycles adapted to local conditions, rather than the use of inputs with adverse effects. Organic Agriculture combines tradition, innovation and science to benefit the shared environment and promote fair relationships and a good quality of life for all involved (IFOAM, 2017; http://www.ifoam.bio/). In general, it reduces the vulnerability of farmers as the higher organic prices act as buffer against the low prices and price volatility of conventional markets, as organic systems are often more resilient against extreme weather events, and as the often diverse organic crop-livestock systems offer a diverse set of outputs.

Environmental friendly agricultural production area (organic, no-pesticide, and low-pesticide) in Korea has been steadily decreasing since 2012 due to tightening the certification of environmental friendly agricultural products. However, compared to 2015, the cultivation area of certified environmental friendly products and the number of certified farms increased by 5.8% (79,479 ha) and 3.2% (61,946), respectively in 2016. The cultivation area of environmentally friendly agricultural products has been rebounding for the first time in four years since 2012. In particular, the area of certified organic products and the number of certified organic farms increased by 9.5% (19,862 ha) and 11.1% (12,896) in 2016 compared to 2015. To support this growth of organic agriculture in Korea, research and development in organic farming must be accompanied because organic farmers need scientific technologies for its stable production. Moreover, the demand for technology development for organic agriculture by farmers is increasing as the low-pesticide certification system is abolished in 2015.

The Rural Development Administration (RDA) has been established for the purpose of promoting rural areas and contributing to national development since 1962. Organic Agriculture Division (OAD) was newly established to develop practical technologies for organic crop production at the National Institute of Agricultural Sciences (NAS), RDA in 2004. OAD has largely developed various organic farming technologies to supporting small scale farmers and these technologies are distributed to the farmers.

In this paper, we will describe the researches of RDA on development of organic farming system, soil and nutrient management, and crop protection technology. In addition, future plan including the dissemination of organic technology, future research directions, public-private partnerships, and international cooperation will be introduced to assist organic farmers.

RESEARCH AND DEVELOPMENT ON ORGANIC AGRICULTURE IN KOREA

Rural Development Administration organization

RDA was established for the purpose of promoting rural areas and contributing to national development in 1962. It has been actively engaged in research, development and dissemination of science and technology related to agriculture, farmers, and rural areas, rural education, education and training, and international cooperation in order to promote agriculture development and improve the welfare of farmers and efficient use of rural resources. RDA is composed of the headquarters including Planning and Coordination Bureau, Research Policy Bureau, Extension Service Bureau, and Technology Cooperation Bureau, four research institutes including National Institute of Agricultural Sciences (NAS), National Institute of Crop Science (NICS), National Institute of Horticultural and Herbal Science (NIHHS) and National Institute of Animal Science (NIAS) and Foundation of Agri. Tech. Commercialization & Transfer (FACT) (Fig. 1). RDA also maintains a close cooperation with Provincial Agricultural Research & Extension Services, City/County Agricultural Technology Centers, and Regional Specialization Agriculture Experiment Centers for agricultural research and technology dissemination.
Organic agricultural research

Organic Agriculture Division (OAD) was newly established to develop practical technologies for organic crop production at the National Institute of Agricultural Sciences (NAS), Rural Development Administration (RDA) in 2004. OAD has largely developed various organic farming technologies to support small-scale farmers and distribute them to the farmers. Research projects related to organic farming are selected through stakeholders’ committee based on research roadmap of RDA, policy demand, and on-site needs from farmers. Research main topics of OAD are as follows: development of organic farming system and crop protection technologies, and assessment of environmental and ecological impacts of organic farming. Fifteen researchers are working in laboratory of organic agricultural land management, crop protection, organic environment & ecology of OAD. The research fund of OAD is about US$3,620,000 including US$1,410,000 and US$2,210,000 for ordinary and cooperation researches in 2017.

Organic soil and nutrient management in organic farming in Korea

Green manure as alternatives for chemical fertilizer

Green manure cultivation helps to maintain and improve organic matters in soil, suppress crop pest occurrence, supply plant nutrients with high quality, and prevent soil erosion. It especially increases biological activity of soil microorganisms and nitrogen fixation, helps nutrient circulation from sub soils to surface soils, prevents nutrient loss, and conserves nutrients by crop rotation with green manures.

NICS researchers confirmed that cultivation of hairy vetch could replace nitrogenous fertilizer in rice paddy field by sowing 6-9 kg of hairy vetch seed per 1,000m² in early October. They also selected seven kinds of barley as green manure crop before transplanting rice for the supply of nitrogen, phosphorous and potassium for organic crop production. In order to select barley varieties that can replace rye, which is imported from foreign countries, they tested several barley varieties as green manure in Suwon-si, Gyeonggi province (central and northern regions), Yesan-si, Chungnam province (middle and southern regions), Daegu Metropolitan city (Yeongnam region) and Naju-si, Jeonnam province (Honam region). The selection criteria for barley varieties were as follows: high wintering rate, less than 35% of C/N ratio at the middle of May due to the rice transit period (from the end of May to the beginning of June), rapid composting after the incorporation into paddy soil, more than 1.5 ton of biomass production per 1,000m². As results, they found that seven barley varieties were suitable for green manure crop in paddy field: three varieties such as Youngyangbori, Sangnokbori, and Paldobori in central and northern regions, four varieties such as Youngyangbori, Geongangbori, Olbori, and Gwanganbori in central and southern regions, and three varieties such as Gwanganbori, Youngyangbori, and Keunalbori.
Liquid fertilizers for organic crop production

Liquid fertilizers not only supply the nutrients needed by plants, but also activate beneficial microorganisms in the soil (Park et al., 2001). Nutrients and microbial fermentation products of liquid fertilizers are known to have beneficial effects on various aspects of crop growth, including root protection and rooting promotion (Kai et al., 1990; Elad and Shlitenberg 1994).

An et al. (2012) surveyed actual usage status of farm-made liquid fertilizers by investigating their formulation types, materials, manufacturing and using methods and various beneficial effects for crops on 29 farms certified by National Agricultural Products Quality Management Service (NAQS) to produce environmental friendly agricultural products in 2009. Most of the materials, including rice bran, bone meal, fish by-product, egg shell, sesame stem and so on, used to make liquid fertilizers are those that can be easily obtained around the farms (Table 1). The types of the farm-made liquid fertilizers were as follows; fermented liquid fertilizers, fermented plant juices, amino acid liquid fertilizers, calcium-liquid fertilizers, and phosphoric acid liquid fertilizers (Table 1). They found that liquid fertilizers used by the farmers promote plant growth by supplying nutrition, accelerate blooming and flower bud formation, enhance the quality of agricultural products such as increase of sugar contents and improvement of storing conditions, induce resistance against diseases and insect pests, and cause endurance to high temperature stress (Table 2).

They also analyzed chemical properties of the collected liquid fertilizers and found that the range of pH and EC had differences according to kinds of the liquid fertilizers. The amount of macro-nutrients, such as nitrogen and phosphorus, in most of the collected liquid fertilizers, was found to be low. Even if the liquid fertilizers were made from same materials, their components were different depending on the making process.

Table 1. Classification of farm-made liquid fertilizers and materials used (An et al., 2012)

<table>
<thead>
<tr>
<th>Classification</th>
<th>Materials used</th>
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<tbody>
<tr>
<td>Fermented liquid fertilizer</td>
<td>rice bran, soybean meal, bone meal, apple, pear, plum, kiwi, persimmon, peach, mongolian dandelion, water celery, igmocho, japanese hop, purslane, persimmon peel, tomato, ginkgo nut peel, spring onion, onion, food by-product</td>
</tr>
<tr>
<td>Fermented plant juice</td>
<td>pear, akebia quinata fruit, paprika, kiwi, mugwort, water celery, ginseng, seaweed</td>
</tr>
<tr>
<td>Amino acid</td>
<td>fish, fish by-product (bone, gut), fish sauce by-product</td>
</tr>
<tr>
<td>Calcium</td>
<td>egg shell, clams hell, oyster shell, crab shell, shrimp shell, bone meal</td>
</tr>
<tr>
<td>Phosphorus</td>
<td>sesame stem, perilla stem, rice bran</td>
</tr>
<tr>
<td>Others</td>
<td>phyllite, guano</td>
</tr>
</tbody>
</table>

Table 2. Effect of farm-made liquid fertilizers on growing characteristics of cultivated crops (An et al., 2012)

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Effects</th>
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<tbody>
<tr>
<td>Growth</td>
<td>supplying nutrition, blooming and forming flower bud acceleration, renewal of plant, growth promoter</td>
</tr>
<tr>
<td>Quality</td>
<td>increasing sugar content, extending storage period, fruit bearing and coloration accelerator</td>
</tr>
<tr>
<td>Resistance</td>
<td>increasing a resistance against disease and insect pests, tolerance to high temperature and cold</td>
</tr>
</tbody>
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Composts for organic crop production

In Korea’s organic farming system, fully decomposed composts are used to supply nutrients with good quality to plants, improve soil physical properties by soil aggregation, increase water- and nutrient-holding capacity, promote effective microbial population, and suppress soil-borne plant diseases. Compost materials are classified by nutrient components (Table 3). As an ongoing study, researchers of RDA are investigating the antagonistic activities of garlic by-product composts against three soil-borne plant pathogens (SBPs), Sclerotinia sclerotiorum, Ralstonia solanacearum and Fusarium oxysporum.
Table 3. Compost materials classified based on nutrient components

<table>
<thead>
<tr>
<th>Nutrients</th>
<th>Compost materials</th>
</tr>
</thead>
</table>
| Nitrogen  | • By-product: sawdust, rice husk, bark, rice straw  
|           | • Livestock manure: cattle, swine, poultry  
|           | • Plant residue herbal/animal materials: rice bran, oil cake, fish meal, blood meal |
| Phosphorous | • Rice bran, meat bone meal, calcined bone meal, rock phosphate, guano |
| Potassium | • Compost, rock powder, illite, ashes, potassium chloride, potassium sulfate, potassium(manganese) sulfate |
| Calcium | • Dolomite limestone, lime stone, shell powder, egg shell, oyster shell, crab shell |

**Plant disease management**

**Resistant cultivar**

RDA researchers selected resistant varieties focused on cash crops for plant disease management. *Phytophthora* blight diseases severely occurred in potatoes and pepper fields (Fig. 2 and Fig. 3). Resistant varieties of several crops including rice, pepper, Chinese cabbage, potato, tomato, garlic, and ginger have been selected and cultivated in the organic farmers’ field for suppressing plant diseases.

**Mix-cultivation**

In general, mix-cultivation is a type of agricultural cropping system that implies planting two or more crops in the same field. The advantages of mix-cultivation are known to balance gain and loss of soil nutrients, to suppress weeds, insect pests, and plant diseases, to resist climate extremes such as wet, dry, hot, and cold, and to increase overall productivity. RDA researchers evaluated the effect of mix-cultivation on potato late blight by mix-cropping potato and resistant potato variety, soybean and corn. Through this study, they found that the mix-cultivation of potato, soybean and corn could suppress the potato late blight effectively compared to potato monoculture (Fig. 4).
**Grafting**

In the case of hot pepper, the researchers were partly graft-cultivated to control pepper *Phytophthora* blight and to improve nutrient adsorption ability in few organic farmers’ fields (Fig. 5). Recently, practical use of grafting of pepper in the field is about 3%. When peppers were graft-cultivated, pepper *Phytophthora* blight could be controlled over 95% of control value.

![Grafting field](image)

**Fig. 5.** Grafting of pepper (left: resistant stock for pepper *Phytophthora* blight) and damage of pepper Phytophthora blight in non-grafting field (right)

**Crop rotation**

Crop rotation is the most important and fundamental skill in organic farming. This has the advantage of establishing nutrients in the soil (Havlin *et al*., 1990), and helping control crop diseases (Kim *et al*., 2012; Kim *et al*., 2009), pests (Kim *et al*., 2014), and weeds (Lee *et al*., 2012).

Han *et al.* (2015) conducted the study to evaluate the effect of crop rotation cultivation on the suppression of garlic white rot caused by *Sclerotium cepivorum* in the mini plot (2×1×0.5 m). Six crops, soybean, sesame, mungbean, squash, crotalaria and spring onion, were previously transplanted in the mini-plots infested with *S. cepivorum* before garlics were planted. After cultivation of the previous crops, garlic was sown in the mini-plot.

Non pre-cultivation plots and non-infested plots with white rot pathogen were used as control. The effect of crop rotation cultivation on the suppression of garlic white rot was evaluated by investigating comparatively the disease incidence (the percentage of infected plants) and yields. As a result, infection rate of garlic white rot was recorded lower in the non-infested plot, crotalaria and soybean cultivation than in the plot of the other crop cultivation. Especially when squash was previously cultivated and garlics were planted in 2013, infection rate of garlic white was recorded the highest score.

In 2014, the infection rate of garlic white was low in the garlic on soybean, crotalaria and spring onion treatment whereas it was high in squash treatment, as well. In 2013, garlic yield was the highest in no inoculation plot, followed by crotalaria, soybean, no crop cultivation, sesami, mungbean, squash cultivation plot (Fig. 6). The yield in the plot of crotalaria and soybean was much higher than that in no inoculation plot. Based
on above-described results, it is considered that soybean-garlic and crotalaria-garlic cultivation system can be good crop rotation systems to control garlic white rot (Fig. 7).

**Fig. 6.** Effect of crop rotation cultivation on the development of white rot caused by *Sclerotium cepivorum* in the mini plot in 2013 (a) and 2014 (b) (Han et al., 2015).

**Fig. 7.** Suppressive effect of crop rotation cultivation on the development of white rot in 2013 and 2014 (Han et al., 2015).

**Green manure cultivation**
Recently, researchers of JeollaBuk-do Agricultural Research and Extension Services (JBARES) tested the effect of rye cultivation as green manure on suppression of the soil-borne disease, pepper *Phytophthora* blight, in pepper field. In their study, the onset time of pepper *Phytophthora* blight was delayed by 38 days and disease incidence was reduced by 43.9% compared to conventional cultivation when ryes were pre-cultivated and soil-applied, and high ridged cultivated. They also found that pepper bacterial blight could be easily controlled by the same method. They will further study the effect of green manure cultivation against the other soil-borne diseases including Sclerota-forming diseases, *Fusarium* wilt, and damping-off, etc.

**Solarization**
Solarization is one of good control measures against soil-borne diseases. It is used to control soil-borne diseases under the plastic film house condition. Chinese cabbage club root is soil-borne and occurred severely in Korea. However, only few resistant varieties against the disease were developed. RDA researchers tried to control Chinese cabbage club root by using solarization method in both the open field and the plastic film house. In the open field trial, solarization had no effect in controlling the disease, but in the plastic film house, it could control the disease effectively with more than 90% of control value (Table 4). Solarization is commonly applied a month in the plastic film house on July to August (hot summer season in Korea).
Table 4. Control value of Chinese cabbage club root by solarization

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Control value (%)</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Open field</td>
</tr>
<tr>
<td>Solarization</td>
<td>ND</td>
</tr>
<tr>
<td>Solarization + fungicide</td>
<td>29</td>
</tr>
<tr>
<td>Fungicide</td>
<td>12</td>
</tr>
<tr>
<td>Non-treated</td>
<td>0</td>
</tr>
</tbody>
</table>

**Rain proof**
Pepper anthracnose pathogens are generally disseminated abruptly in rainy days with wind. RDA researchers developed rain proof facility for preventing the rain or wind, and installed that in organic pepper field and cultivated pepper. As results, anthracnose incidence was very low in rain proof facility compared to open field. The control value was more than 98% and pepper production was increased by 25% (Fig. 8). The advantage of developed rain proof facility is cheaper than the installation of greenhouse and easy to manage similar to open field condition. Recently, it is being used to control the pepper anthracnose nationwide in organic farm houses in Korea.

![Fig. 8. Effects of blocking rain splash on control of pepper anthracnose by Colletotrichum acuatum](image)

**Air-circulation fan**
In general, high relative humidity is needed by plant pathogens to penetrate into plant tissues. RDA researchers investigated the effect of circulation fan installation on the development of strawberry powdery mildew. They found that circulation fan installation reduced the incidence of strawberry powdery mildew. In addition, they measured microclimates including CO₂ concentration, ambient temperature, and relative humidity. When the fan was operated in the plastic film house, the CO₂ concentration increased during day time and decreased at night time. They thought that CO₂ increase during day time is helpful for photosynthesis of plants because plants photosynthesize during day time. Relative humidity decreased at night time. They believed that the decrease of relative humidity at night time could suppress the plant pathogens to penetrate into the plant tissues. Finally, they confirmed that air-circulation fan installation could reduce the incidence of strawberry powdery mildew and increase the strawberry yield. Recently, air-circulation fan is being used to control the cucumber downy mildew, tomato gray/leaf mold, and among others. Therefore, air-circulation fan could be one of good control measures against air-borne diseases including strawberry powdery mildew.

**Microbial fungicides**
Some microbial fungicides were developed by RDA researchers. First, they collected the antagonistic bacterium (Paenibacillus polymyxa) from pepper root and found that it has high antifungal activity for controlling the cucumber powdery mildew, rose powdery mildew, and pepper Phytophthora blight (Kim et al. 2013) (Fig. 9). Now, this microbial fungicide (TOPSEED) is commercially being used in Korea.
Fig. 9. The antagonistic effects of *Paenibacillus polymyxa* on cucumber powdery mildew, rose powdery mildew and pepper *Phytophthora* blight in *P. polymyxa* (TOPSEED) treated and untreated plot.

Second, they selected the hyper-parasite microorganism (*Ampelomyces quisqualis*) showing high penetrating activity against powdery mildew pathogens and developed microbial fungicide for controlling powdery mildews (Lee *et al.*, 2007) including powdery mildews of strawberry, rose, and cucumber, among others (Fig. 10).

Fig. 10. The antagonistic effects of *Ampelomyces quisqualis* on strawberry powdery mildew in *A. quisqualis* (Q-Pect) treated and untreated plot.

Third, the plant growth promoting rhizo-bacteria, *Bacillus vallismortis*, showing various functions including induced disease resistance activity was selected and developed as organic materials by RDA researchers (Part *et al.*, 2007) They confirmed that the product (EXTN-1) application could control several fungal, bacterial and viral diseases such as tomato bacterial wilt and cucumber anthracnose (Fig. 11).

Fig. 11. The suppressive effects of *Bacillus vallismortis* (EXTN-1) on tomato bacterial wilt in EXTN-1 treated and untreated plot.

**Representative eco-friendly materials**

In Korea, several kinds of environmentally friendly commercial products are being used to control plant diseases. RDA researchers developed a new formulation which is Cooking Oil and egg-Yolk (COY) mixture for controlling crop pests. The formulation was made by mixing cooking oil and egg yolk (Fig. 12 and Table 5). This is commonly used in Korea for the control of various plant diseases and insect pests in organic crop protection. Oil has suppressive effect against plant diseases and insect pests. However, oil is not suspended in water. Therefore they used egg yolk as an emulsifier. Finally, they mixed cooking oil and egg yolk, and termed as COY mixture.
A new soluble sulfur formulation was developed as an alternative of Bordeaux mixture by adding sodium hydroxide to sulfur. The formulation method of the soluble sulfur compound is very simple as shown in the Fig. 9. Materials of soluble sulfur compound are sulfur powder, sodium hydroxide, sea salt and loess. Because heat occurred during reaction time between sulfur and sodium hydroxide, people should pay attention to it (Fig. 13). This soluble sulfur is a liquid form of sulfur powder and widely used for the control of various diseases in organic fruit and vegetables. Foliar application of the soluble sulfur significantly suppressed pepper powdery mildew at 88.9% of control value.

Insect pest management

Green manure cultivation

Several cover crops have been used to control weeds in organic farming. However, the effect of cover crops on the pest and natural enemy population has rarely been studied in Korea. Han et al. (2013) investigated the effects of leguminous plant, *Vicia tetrasperma*, on the occurrence of insect pests and their natural enemies in pepper field. To estimate the effect of cover-crop on arthropod diversities and occurrences of insect pest in pepper, *V. tetrasperma* was sowed as cover-crop plot October, 2008 and 2009. Control plot was kept bare in winter season and mulched with black plastic-film before transplanting red pepper seedlings. Pepper seedlings, *Capsicum annuum*, were transplanted on the 19th of May, 2009 and on the 20th of May, 2010, respectively. Five Yellow sticky traps were set and changed at 7 days interval. Densities of aphids and thrips and damaged fruit rates by oriental tobacco budworm, *Helicoverpa assulta*, were counted.

Populations of aphids, thrips and braconid wasps were maintained high on *V. tetrasperma* before transplanting pepper seedlings and in early season of pepper. However, the densities of aphids on pepper in the control plot were much higher than in the cover-crop plot in the early stage of pepper (Fig. 14, and Fig. 15).
Fig. 14. Populations (Mean ± SE) of aphids (a) and thrips (b) in cover crop, *Vicia tatrasperma*, plot and control plot in 2009 (Han et al. 2013)

* Asterisks indicate statistically significant differences according to T-test at 95% level.

Fig. 15. Populations (Mean ± SE) of spiders (a), lady beetles (b), braconid wasps (c), and lace wings (d) in cover crop, *Vicia tatrasperma*, plot and control plot in 2009 (Han et al. 2013)

* Asterisks indicate statistically significant differences according to T-test at 95% level
**Push-pull strategy**

Studies on push-pull strategy are currently being implemented for insect pest management in organic agriculture. Han *et al.* (2015) evaluated two herbal plants, basil (*Ocimum basilicum*) and lemon balm (*Melissa officinalis*), for their potential as repellent plants in the management of striped flea beetle (*Phyllotreta striolata*), in organic production of Chinese cabbage. It was confirmed that striped flea beetle avoided these two herbal plants in olfactometer experiment (Fig. 16).

They conducted field experiment in which the suppressive effect of the two selected herbal plants and cruciferous crops preferred by striped flea beetle were evaluated through cultivating as inter crops and border crops, respectively. In inter-cropping experiment, unlike *in vitro* test, the density of striped flea beetle was low in basil- or mustard-intercropping cultivation plot, but high in lemon balm-intercropping cultivation plot. In border cropping experiment, the densities of striped flea beetle on Chinese cabbage in lemon balm or basil cultivation plot were approximately zero (Fig. 17). As a result of this study, they think that border cropping of lemon balm or basil can be used to reduce preventively striped flea beetle of Chinese cabbage under organic farming system.

![Fig. 16](image1.png)

**Fig. 16.** Evaluation of repellent effect of assemblage (combined treatment) of each two herbal plants and Chinese cabbage against striped flea beetle using Y-tube olfactometer compared with Chinese cabbage alone (Han *et al.*, 2015).

![Fig. 17](image2.png)

**Fig. 17.** Field evaluation of inter-cropping effect of two repellent plants and three attractant plants against striped flea beetle in 2013 (Han *et al.*, 2015).

**Insect traps**

For insect pest monitoring and attraction, diverse pest traps are used in greenhouses and open fields. Sugar traps have been used to attract flies, but they are rarely used in recent years. Light traps are used to attract moth pests using phototaxis of insects. Yellow sticky traps are most commonly used in greenhouses and are mainly used for insect inspections such as aphids, thrips, and whiteflies. Pheromone traps are used for mating disruption of moth pest, oriental tobacco budworm (*Helicoverpa assulta*), Oriental fruit moth (*Grapholita molesta*), and peach fruit moth (*Carposina sasakii*) in hot pepper, apples and pear orchards.
**Plant extract: natural insecticides**

Various plant extracts such as Pyrethrum, Neem, Derris, Sophora, and others showing insecticidal activity against several insects are widely used to control the insect pests in Korea. Pyrethrum is derived from the dried flower heads of the pyrethrum daisy, mainly *Chrysanthemum cinerariaefolium* and contains pyrethroid compounds showing insecticidal effect by nerve palsy against aphids, leaf miners, moths, and so on. Neem oil is from fruits and seeds of neem tree and has azadiractin compounds showing an anti-feeding, anti-molting, and anti-oviposition activity against several insects. Derris is natural insecticide extracted from root of leguminous plants, *Derris elliptica*, and has rotenone compounds that block mitochondrial electron transport system of insects like cockroaches, mites, cucurbit leaf beetles, etc. Sophora is plant extract from root of leguminous plants, *Sophora flavescens*, and has several alkaloids with insecticidal effect with nerve palsy and anti-respiration against several insects. Recently, RDA researchers found that the extracts of red pepper and its seeds inhibited the initial influx of bean bug, *Riptortus clavatus*, in soybean field (Fig. 18).

![Fig. 18. Density changes of bean bugs, *Riptortus clavatus*, after ginger, garlic, pepper, pepper-seed, and spring onions extract were prayed in bean field (unpublished data).](image)

**Biological control**

Studies on biological control of insect pests have been actively conducted and discussed the ecology and utilization technologies of introduced and indigenous natural enemy species from the mid-1990s to mid-2000s. Since 2005, the Ministry of Agriculture, Food and Rural Affairs (MAFRA) has been supporting environmentally friendly agriculture with 50% of the purchase of natural enemies as national expense. Therefore, the agricultural area where natural enemies are used has increased from 321 ha in 2005 to 2,680 ha in 2010. However, due to some poor quality of commercial natural enemies, illegal supply and demand of farmers and natural enemy companies, and failure to differentiate prices of agricultural products used by natural enemies, the support from MAFRA has been discontinued and the natural enemy industry has been shrinking since 2010.

As an example of biological control using natural enemies, the effect of natural enemies on densities of four major pests (aphids, thrips, whitefly, and mite) of hot pepper was tested in greenhouses of Wanggung-myeon, Jeollabuk-do from 2009 to 2010 (Kim et al., 2012). The aphid densities were successfully suppressed by introducing three *Aphidius colemani*-banker plants, and releasing 23.3 wasps per m² on April 16 and 23 wasps per m² in a greenhouse of 660 m² (Fig. 19). To control thrips, *Orius laevigatus* was released twice, 3.0 bugs per m² at a time (May 11th and June 12th). The thrips population was controlled within 0.3 thrips per flower during the growing season (Fig. 20). To control two species of mites, *Tetranychus kanzawai* (kanzawa spidermite) and *Polyphagotarsonemus latus* (broad mite), and the silverleaf whitefly, *Bemisia tabaci*, a total of 113.7 individuals of *Amblyseius swirskii* were released twice (May 11th and 30th). The densities of *B. tabaci* and *T. kanzawai* were kept within 171.0 individuals/trap and 0.8 individual/leaf, respectively (Fig. 21, 22). *P. latus* was suppressed completely twelve days after release. The cost of the released natural enemies to control the four arthropod pests in this study was about US$370 per 660 m².
Fig. 19. Control efficacy of braconid parasitoid *A. colemani* against aphids on hot pepper in a protected greenhouse in 2009 (A) and 2010 (B).

Fig. 20. Control efficacy of pirate bug *O. laevigatus* against thrips on hot pepper in a protected greenhouse in 2009 (A) and 2010 (B).

Fig. 21. Control efficacy of predatory mite *A. swirskii* against *B. tabaci* on hot pepper in a protected greenhouse in 2009 (A) and 2010 (B).
Fig. 22. Control efficacy of predatory mite *A. swirskii* against *T. kanzawai* (A) and *P. latus* (B) on hot pepper in a protected greenhouse in 2009.

Recently, Park et al. (2015) tested the control effect of entomopathogenic microagent against the beet armyworm, *Spodoptera exigua*, on organic Chinese cabbage. In greenhouse experiment, the control value of BT and nematode mixture treatment was higher than BT and nematode treatment alone against *S. exigua* (Fig. 23). In treatment of 107 PIBs/ml of SeNPV, *S. exigua* was controlled completely. In farm condition, mixture of microbial agent and organic agricultural material showed higher control value against lepidopteran pest including *S. exigua* than BT single treatment (Fig. 24).

Fig. 23. Control efficacy of *Bacillus thuringiensis* and *Steinemema carpocapsae* mixture against beet armyworm, *Spodoptera exigua*, of Chinese cabbage on plastic house. The same letter over the bars in each treatment indicates that there is no significant difference among means (p<0.05).

* Bt: *B. thuringiensis* (2×105 cfu/ml), Sc: *S. carpocapsae* (2×102 nematodes/ml)

Fig. 24. Control efficacy of microbial agent against pest of Chinese cabbage on organic farm. The same letter over the bars in each treatment indicates that there is no significant difference among means (p<0.05).

*Mix: Bacillus thuringiensis + oxymatrin (1st treatment), B. thuringiensis + SeNPV (2nd treatment), Bt: B. thuringiensis treatment.*
Future plan

**Organic farming technology dissemination**
We will publish an organic farming guide books or booklets for the dissemination of the developed organic farming technologies, and continue education for organic farmers through cooperation of RDA and local government. Twenty-eight organic farming guide books, including grapes, citrus fruits, and so on, have been published until 2016, and additional and revised manual will be published until 2021. We will cooperate with Provincial Agricultural Research & Extension Services and City/County Agricultural Technology Centers to educate rural guidance officials for utilizing organic farming techniques. Moreover, we will also continue to upload organic technologies to the RDA website (www.nongsaro.go.kr) to provide up-to-date information to farmers.

**Reinforcement of organic agriculture research**
Until now, organic farming researches have been focused on organic soil and nutrient management, disease, pest and weed control, organic seeds, organic agricultural materials, and publications of organic farming guide books. In the future, we will study on the safety and functional ingredients of organic agricultural products with high public interest, biodiversity in organic agriculture, carbon reduction and climate change, processing of organic agricultural products, and environmental impact assessment for organic farming.

**Public-private partnership: Organic Technical Committee**
Organic Technical Committee (OTC) has been organized for cooperation between government and private sector of organic farming since 2005. OTC consists of RDA, Ministry of Agriculture, Food and Rural Affairs (MAFRA), National Agricultural products Quality management Service (NAQS), NongHyup, farmers, private organizations for environment-friendly agriculture, and professors. NAS is continuously going to manage OTC for the discussion of organic agriculture and cooperative plan, planning early settlement of organic agriculture in Korea, and dissemination of organic farming technologies.

**International cooperation**
We carried out the collaboration projects on control of apple pests using vegetation management with Forschungsinstitut für biologischen Landbau (FiBL), assessing the environmental eco-benefits of organic farming with Thünen Institut (TI), characterization of soil properties of organic farm land with National Agriculture and Food Research Organization (NARO), and Eco-compensation by promoting environmentally-friendly agricultural technologies in China and South Korea with Chinese Academy of Agricultural Sciences (CAAS). We will continue to cooperate with international institutions in the future and will explore new international collaborative researches.

In order to establish the base of organic agriculture, we have been organizing an organic guidance specialist training program jointly with IFOAM to nurture outstanding organic experts and will continuously organize that program. We also have been managing Organic Farming Innovation Award (OFIA) committee and will proceed with OFIA ceremony in the 19th World Organic Congress held in India on November, 2017.

In addition, the Asian Food and Agriculture Cooperation Initiative (AFACI) is an inter-governmental and multi-lateral cooperation group aiming to improve food production, realize sustainable agriculture and enhance extension service of Asian countries by sharing knowledge and information on agriculture including organic farming technology, organic farming system, and establishment of successful model of organic agricultural village. AFACI is composed of fourteen member countries: Bangladesh, Cambodia, Lao PDR, Indonesia, Kyrgyzstan, Mongolia, Nepal, Philippines, Sri Lanka, Thailand, Vietnam and Korea; and Bhutan and Myanmar which memberships have been effective year 2016. Its Secretariat is located at International Technology Cooperation Center (ITCC), Rural Development Administration in Joenju, Korea. We will continue to promote international trainings program, workshops and symposiums with AFACI.
CONCLUSION

The global organic food market is about US$80 billion and growing every year. It is also expected to grow continuously due to increased consumer interest in food safety and value conscious consumption. In 2015, there are 2.4 million organic agriculture producers, 1/3 of them are in Asia, and it has been 10 times increase in the number since 1999. Organic cultivation area and organic farmers in Korea is also increasing recently.

As we mentioned, the area of certified organic products and a number of certified organic farms remarkably increased in Korea, 2016. For these reasons, research and development on organic farming must be reinforced for the increase of organic production. The spread of environmentally friendly technologies should also be strengthened because 70% of environmentally friendly farmers have difficulty in controlling plant disease, pests and weeds.

Researches on organic agriculture in Korea have been focused on organic soil and nutrient management, disease, pest and weed control, organic seeds, organic agricultural materials, and publications of organic farming guide books. In the future, we will try to do studies on the safety and functional ingredients of organic agricultural products with high public interest, biodiversity in organic agriculture, carbon reduction and climate change, processing of organic agricultural products, environmental impact assessment for organic farming, and organic management technology for local special crops in response to needs of farmers and consumers. In addition, it will be continued to promote the spread of organic technologies and international cooperation developed for assisting organic farmers at the inside and outside of the Korea.

REFERENCES


