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Driving Strategies and Mechanical Technologies for Conservation Agriculture in Korea

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Abstract

Agriculture has been continued as a life-industry in harmony with ecosystem by reproduction using solar energy in material cycle system. Agriculture in Korea, however, has increased environmental load (or damage) due to intensive production system with limited natural resources.

To solve these problems and realize sustainable agriculture while keeping balance among materials in ecosystems, Korea has been continuously promoting environmental-friendly agriculture. Long-term goal of reduction in chemical fertilizers and pesticides was set up and pursued, land area and household for environmental-friendly crop production were increased, and amount of certified environmental-friendly agricultural products will be increased gradually.

As an alternative to realize environmental-friendly agriculture, Korea has been developing technologies related to precision agriculture, and promoting applicable models suitable for Korean situation. Precision agriculture differs from organic agriculture that do not use any chemical agricultural materials, but is expected to settle as a low input sustainable agriculture, because of practical aspect that precision agriculture conducts scientific agriculture using sensors and machinery, which is also suitable for large-sized farming. In addition, various technologies have been developed and applied to farming for conservation agriculture.

Obstacles that Korea agriculture has for conservation agriculture are small-sized farming plot, petty farming structure, aging of agricultural labor, farmers' lack of environmental-friendly business mind. In spite of these obstacles, Korea has put much efforts in developing and applying policy and technology for conservation agriculture, based on high-level IT and BT, research and development capabilities. Therefore, environmental-friendly agriculture is expected to be a major trend of Korean agriculture in the near future, walk out of N-over-applying OECD countries.

1. Introduction

For conservation agriculture, Korea puts focus on developing and fostering environmental-friendly agriculture, mainly based on the concept of sustainable agriculture. Since 1992 when, in The Rio Declaration, the concept of sustainable agriculture was defined as "accomplishment of sustainable economic growth in harmony of environment conservation with economic development", agricultural field defined sustainable agriculture in the practice agenda (UN agenda 21) as "agriculture minimizing environmental damage while securing long-term productivity and profitability". The meaning can be stated also as "environmentally sound, economically viable, and socially acceptable agricultural production activity".

Korea has pushed ahead with plans for fostering and developing environmental-friendly agriculture on a full scale since mid-90s. Background of these Korean activities includes 1) rearing up of environmental friendly agriculture as a core strategic area of future agriculture, 2) increase of consumer's preference to land environment and safety of agricultural products, and 3) expansion of need of agricultural transformation for environment conservation, instead of high-input agriculture for productivity.

In addition, an a way to realize environmental friendly agriculture, Korea has been conducting basic experiments and developing technologies related to precision agriculture as a farming strategy for low input sustainable agriculture that conducts agriculture with machinery based on soil, crop, and weather information collected using sensors.

This report describes 1) strategy driving Korean conservation agriculture for environmental friendly agriculture, previous achievement, and future issues to be solved were stated, and 2) current development status and future perspective of mechanical technology for environmental friendly agriculture including precision agriculture, as technologies required to realized environmental friendly agriculture.

2. Policy for environmental friendly agriculture in Korea

2.1 Goals of environmental friendly agriculture in Korea

Korea have been pursuing "environmental friendly agriculture fostering goals" such as reduction of chemical fertilizer and pesticide application, increase of certified environmental friendly agricultural products, build-up of systematic structure for a nature circulation type environmental friendly agriculture, in which sowing and livestock farming are linked.

One of the critical issues to be addressed for sustainable agricultrue is reduction of chemical fertilizer and pesticide application amount. As in Table 1, amount of over-applied fertilizer as compared with that of recommended standard fertilizer was approximately 26% in paddy rice production, as of 2002. Over-applied ratio (%) by component were 29.7, 25.6, and 21.9% for phosphorous, nitrogen, and potassium, respectively.

Table 1. Estimated over-applied fertilizer for paddy rice production (as of 2002)

Component	Recommended rate (kg/10a)	Applied rate (kg/10a)	Over-applied rate (kg/10a)	Over-applied ratio (%)
Nitrogen	11.0	14.8	3.8	25.6
Phosphorous	4.5	6.4	1.9	29.7
Potassium	5.7	7.3	1.6	21.9
Total	21.2	28.5	7.3	25.7

Korea is pursuing a goal to reduce application amount of chemical fertilizer by 40%

from 375 kg/ha in 2003 to 225 kg/ha by 2013. The goal for pesticide amount is also reduction by 40% to 7.4 kg/ha by 2013 as compared with 12.4 kg/ha in 2003.

Table 2. Reduction goals for chemical fertilizer and pesticide application

	2003	2005	2008	2010	2013
Rate per ha (kg/ha)	(100%)				(60%)
- Chemical fertilizer	375	374	290	260	225
- Pesticide	12.4	11.8	10.1	9.1	7.4

Also, Korea plans to increase ratio of certified environmental friendly agricultural products from 4.0% of total agricultural products in 2005 to 7.5% in 2008, and to 10% in 2010.

Table 3. Goal of environmental friendly agricultural products (Unit: thousand ton, %)

	2005	2006	2008	2010
Environmental friendly products (A)	798	940	1,400	1,850
Total agricultural products (B)	18,800	18,700	18,600	18,500
Ratio (A/B)	4	5	7.5	10.0

With these policy to promote environmental friendly agriculture, land area and number of farming household practicing environmental friendly agriculture are expected to reach 114,000 ha and 120,000 household by 2010, as compared with 58,000 ha and 61,900 household in 2006.

2.2 Strategies to foster environmental friendly agriculture in Korea

In Korea, sympathy of need of environmental friendly agriculture is expanding among government, producer, and consumer, and consumers' selection criteria of agricultural products are changing from price to quality and safety, indicating stabilizing of positive condition for environmental friendly agriculture.

Meanwhile encroachment intimidation of Korean organic farming market is increasing due to imported organic agricultural products, and quality deterioration and violation of certification standards is also occurring. And, factors (such as weakness of distribution infrastructure, and difficulty in securing market) threatening expansion of environmental friendly agriculture are present. Therefore, Korea is practicing strategies in various areas to solve these problems, use the change, and develop environmental friendly agriculture(EFA). Promotion strategies by area are summarized as followings.

1) Production area

□ Establishment of nature circulation type agriculture linking sowing and livestock farming
  ○ Environmental friendly organic livestock product: increase to 1% out of total livestock product by 2010

□ Stabilization of farmers' income through increase of EFA direct payment unit cost
  ○ Expansion of environmental friendly livestock farming direct payment to 20% of total registered livestock farming by 2013

□ Establishment of whole year production system through support of EFA technology and material

  ○ Expansion of insect control through natural enemy to 50%(50,000 ha) of the protected horticulture by 2013

2) Distribution area

□ Reduction of distribution cost by construction of distribution center dedicated for EFA products
□ Control of supply-consumption by self-reliance fund for EFA products, activation of publicity
□ Rearing of 30 regional production-distribution base organizations, diversification of distribution channel

3) Consumption area

□ Publicity extension of EFA products, improvement of reliability through after-service control
  ○ Introduction of recall system for entire EFA products by 2010
□ Security of large-volume demand of EFA products (e.g., school meal supply)
□ Groping a way for foreign export of EFA products

4) System area

□ Modification of EFA certification system (e.g., revision of EFA fostering law)
  ○ Abrogation of low-pesticide certification by 2010
□ Transfer of EFA certification to private organization, rearing of private certification organization
□ Expansion of traceability system on a full scale for EFA products
  ○ Operation of full scale traceability system for organic farming household by 2008

5) Agricultural material area

□ Introduction of verification and management of environmental friendly agricultural material (EFAM) (Rural Development Administration, RDA)
□ Analysis of characteristics and effects of EFAM
□ Establishment and operation of laws for management and utilization of livestock waste (or manure)

6) Technology development area

□ Technology development and extension by RDA and research groups
○ Development and extension of EFA standardized technology necessary in the farming fields
□ Resource-making of livestock manure, development of environmental friendly pesticide control technology
□ Development and expansion of processed food using EFA products

7) Local agriculture area

□ Achievement of nutrient balance for regional unit field and reinforcement of agricultural environment resource management
□ Promotion of urban consumers' experience of EFA and interchanges between urban and rural societies
□ Encouragement of participation of local government (e.g., by awarding an EFA prize)

As summarized above, according to the EFA fostering strategy by area, Korea actively promote projects such as establishment and expansion of EFA implementation infra-structure, development and extension of on-farm demanding technology, expansion of nature circulation type EFA linking sowing and livestock farming, support of EFA rearing and income security for EFA practicing household, improvement of consumers' reliability for EFA products and activation of distribution, reduction of rural environmental pollution and reinforcement of international cooperation, and rearing of environmental friendly forestry.

3. Technology development for conservation agriculture

3.1 Precision agriculture (PA) in Korea

3.1.1 Precision agriculture technology development

Korea puts much effort to develop PA technology and feasible application models, as an alternative to realize EFA. PA enables environmental friendly high-quality agriculture in a scientific and effective way using agricultural machinery based on information about soil, crop, and weather. Basic IT-applied PA technologies were developed mainly by the National Institute of Agricultural Engineering, RDA, and it is the stage of on-farm performance test for partial implementation of the results.

Technologies and devices developed or under development are 1) sensors for bio-environment measurement such as soil sampling system, soil strength measuring device, crop growing condition measuring device, and yield monitoring system that measures rice yield by within-field locations, 2) mapping software to create electronic maps, and 3) variable rate initial and additional fertilizer application system.

Soil strength measuring device measures soil strength, an important soil physical property used frequently for hardpan detection and optimum tillage, mechanically and reliably, and commercialization and application to actual farming is expected in the near future.

Fig1. Digital soil strength sensor

One of the devices under on-farm performance test for application to actual farming is an electronic map-based variable fertilizer applicator attachable to a transplanter. The unit uses positioning information (e.g., GPS) and electronic fertilization application map prescribed by soil testing results to apply fertilizer variably by location, and could save 17% of the conventional fertilizer application amount without yield loss.

Fig.2 Map-based variable fertilizer applicator attachable to a transplanter

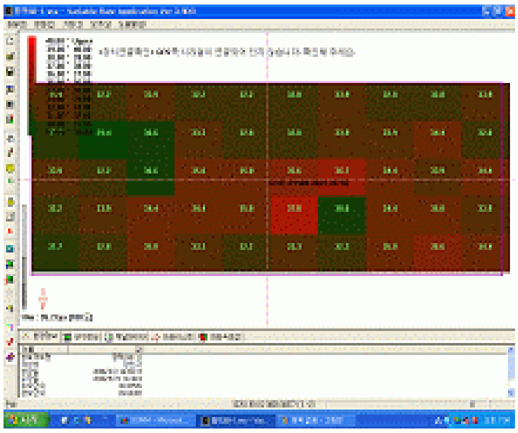

Fig.3 Fertilizer application map by mapping S/W

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Representative example of actual on-farm application is "Ubiquitous-based PA promotion strategy" by Pyeongtaek City. Pyeongtaek conducts projects for development and stable extension of PA technology for environment conservation and high-quality safe agricultural products that consumers prefer.

Other local governments have a big interest in PA and show activities for business plan embodiment and technology adoption, and expansion of PA-based farming operations with technical support is expected.

Fig4.Yield monitoring system

3.1.2 Obstacles and perspectives for Korean PA

As described above, Korean PA is in the stage of basic technology development and on-farm performance test, but for practical application and confirmation of the positive effects, expansion of understanding on PA and development and improvement of Korea-specific application models.

Conceptual approach is more important than technical approach in PA. Instead of simultaneous and full scale application of entire technology, it would be better for Korean agriculture with small sized paddy rice fields to start with application and verification of each technology and expand step by step based on the bio-environmental information.

Through these application strategy, Korea, the most over-applying country of chemical fertilizer and pesticide, would reduce the amount of fertilizer and pesticide application and contribute to sustainable agriculture for production of environmental friendly and safe agricultural products.

3.2 Soil erosion prevention technology

3.2.1 Status of soil erosion in Korea

Most upland fields are located in sloped area, and soil erosion is an important issue since it deteriorate crop productivity and cause environmental pollution. It is reported that in natural condition soil erosion less than 1 MT/ha equilibrates with soil development, and in agricultural field soil erosion should be less than 13 MT/ha to maintain fertility. Removal of natural vegetation, however, increases soil erosion several or several hundred times, and researchers warned annual soil loss up to 485 MT/ha in upland fields using the USLE (Universal Soil Loss Equation).

Loss of fertile ground surface soil causes loss of nutrient, and it was reported that in Korean corn fields with a 20% of slope resulted loss of 15.5 kg of nitrogen, 10 kg of phosphorous, and 21.5 MT of soil particle. Therefore, soil erosion should be recognized as an important issue for EFA and carefully managed. Tillage system is critical to prevent soil erosion, and research results showed that no-tillage for soil conservation could save 62% of soil erosion and 32% of nutrient loss.

3.2.2 Strip-tillage equipment to reduce soil erosion

A strip-tillage equipment that could till only strips to be seeded and the rest of the field covered with chopped rye to reduce soil erosion was developed, and the performance of erosion reduction was evaluated.

3.2.2.1 Strip-tillage equipment

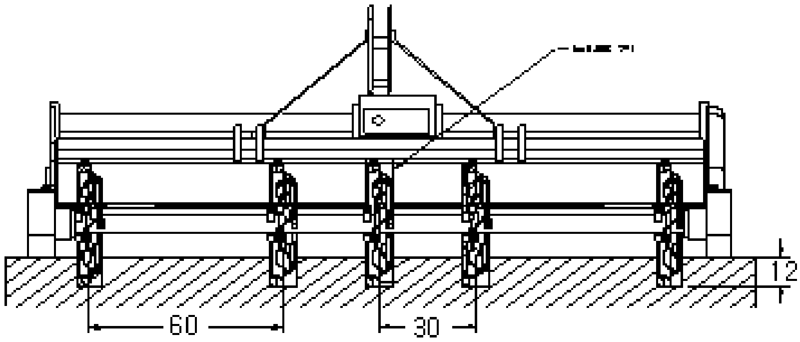
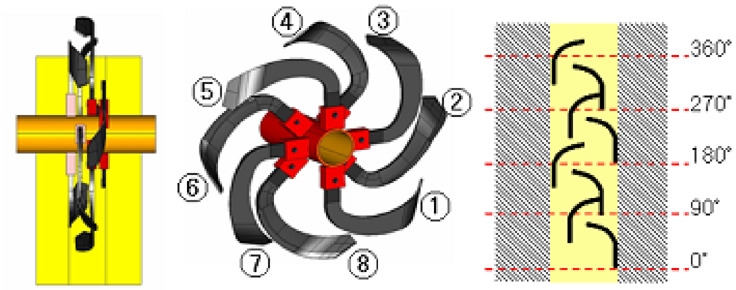


Fig.5 Strip-tillage equipment

The strip-tillage equipment used 8 fodder-chopper type rotary tillage blades for each row to till only strips to be seeded, the row width, tillage depth, and row spacing were 8, 12, 60 cm, respectively, and rotary tillage blades were arranged inwards direction so that scattered soil could in the seeding furrow.



(a) Top view (b) Isometric view (c) Sequence of soilcutting

Fig.6 Tillage blades of strip-tillage equipment

(a) Conventional tillage (up & down)

(b) No-tillage and conventional tillage(contour line)

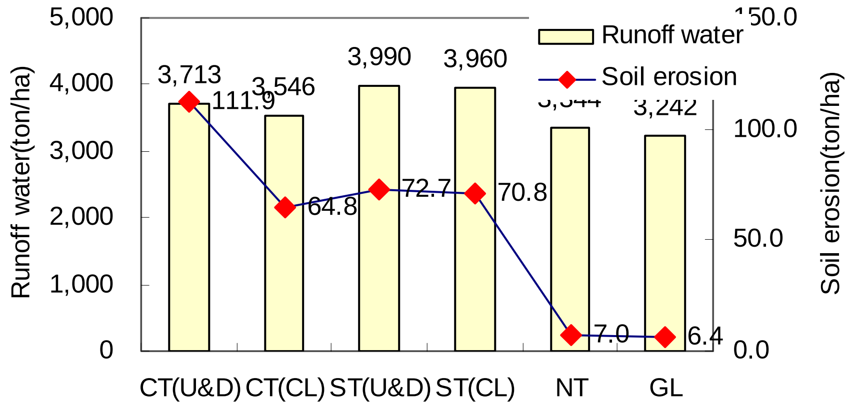
(c) Strip-tillage(contour line)

(d) Strip-tillage(up & down)

Fig.7 Experimental fields

3.2.2.2 Effect of soil conservation by tillage method

Strip-tillage along contour lines caused soil erosion of 70.8 ton/ha, which was 37% less than 111.9 ton/ha for conventional tillage in the up-down direction. The erosion, however, was a little higher than that of conventional tillage along contour lines. Most effective way to reduce soil erosion was to grow cover crops and combine strip-tillage technique.



(CT: Conventional tillage, U&D: Up and down, CL: Contour line,
ST: Strip-tillage, NT: No-tillage, GL: Grassland)

Fig.8 Amount of runoff water and soil erosion by tillage methods

4. Various mechanical technologies for conservation agriculture

4.1 Weeding machine for rice production

A walking type 3-row weeding machine that could remove and root out weeds inter- and within- rows was developed for environmental friendly rice production. The walking type weeding machine for rice production could adjust operating width from 18 to 24 cm according to weeding time, and field capacity was about 10a/h. In a paddy field with a water depth of 1 cm, the use of the prototype was effective in removing weeds, showing a rate of weed control of 97.2%, which was similar with the that of conventional manual weeding operation. This indicated that the prototype could save 94% of weeding labor, and was suitable for EFA with no use of herbicides.

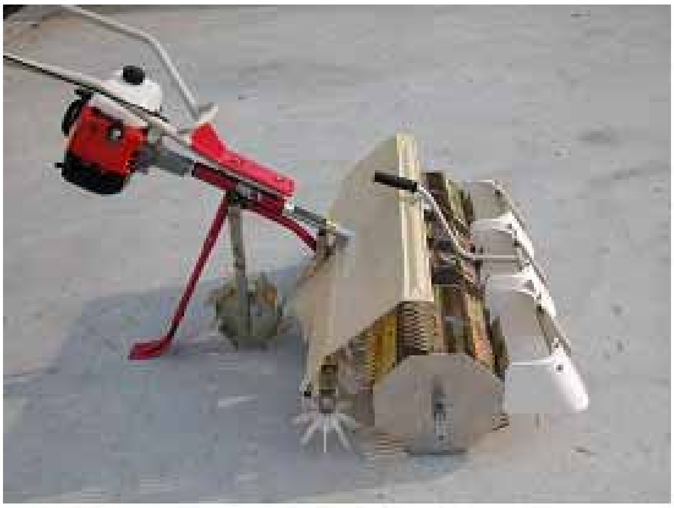


Fig.9 A weeding machine

4.2 A paper-mulching rice transplanter

A paper-mulching rice transplanter was developed to grow rice in an environmental friendly way, by preventing weed growth using paper mulching material, instead of herbicides. Weed-preventing mulch paper was developed in cooperation with a company. The bio-degradable paper (PES, 10 ㎛) was decomposed naturally in 55~60 days after transplanting, and there was no residues in the environment and crop after decomposition.

Field performance of the paper-mulching transplanter showed that weed control value was 98% and rice yield was 502 kg/10a, with no significant difference from 504 kg/10a for conventional transplanter, indicating that the paper-mulching rice transplanter could contribute EFA with no use of herbicides.

Fig.10 A paper-mulching rice transplanter

4.3 A strip-tillage rice transplanter

A strip-tillage rice transplanter that could apply slow-release fertilizers at the time of transplanting was developed to save labor and cost for rice production. The unit could save tillage energy by till only the strips to be transplanted, and increase fertilizer utilization by applying slow-release fertilizers in front of strip-tillage blades and covering the slow-release fertilizer with soil.

Fig.11 A strip-tillage rice transplanter

Field performance tests showed that sufficient irrigation for 10 ~ 20 days before transplanting resulted in reduction of miss-planted rate and increase of rice yield (about 7%), and could save fertilizer application by about 20% compared with conventional transplanting.

4.4 Manual & automatic type inlets and outlets for water management in paddy field

Manual and automatic type inlets and outlets (irrigation gates) replacing conventional soil gates were developed to save labour for water management in paddy field. Developed gates were manual type that could control inflow and outflow by rotating angle (0~90°) of elbow pipes, and automatic type that could open and close gates according to the signal of water level sensors.

These developed gates made flow and water level controls easier, and reduced water management labour and amount of irrigation water significantly. Also, soil loss was minimized by drain starting from surface water by adjusting rotational angle of the elbow pipes. In addition, irrigation water could be saved with prevention of field levee and water leakage by controlling water level automatically, especially in case of heavy rain fall.

Test results showed that gate management capacity were 18.0 h/ha for manual gates and 3.7 h/ha for automatic gates. They were 67% and 14% of that for conventional soil gates (26.8 h/ha). Operational stability and response of water level sensor were fairly good, and water leakage was reduced by 12% for manual type and 93% for automatic type as compared with conventional type.

Fig.12 Automatic type inlet(left) and outlet(right)

4.5 Water proof material to reduce water leakage through the levee and weed growth

Water leakage through field levee was reduced by installing water proof material (e.g., tarpaulin sheet, gum sheet, P.V.C hard panel, light-burned magnesia flour) available easily at farming sites.

(a) No treatment plot (b) Water proof material treatment plot

Fig.13 Weed growth status

The material is installed to a 20 cm depth in the field side to save levee fail and 75% of water leakage. Weed appearance was reduced significantly for levees with tarpaulin sheet, resulting in reduction of weed control labour and time.

5. Conclusions

Korea has been continuously promotes environmental friendly sustainable agriculture with well-developed and detail policy and goals since mid-1990. It is planned to reduce application of chemical fertilizer and pesticide by 2013, and also to expand certified environmental friendly agricultural products gradually by increasing area and number of farming household practicing EFA. To achieve these goals, Korea established promotion strategies by area and 7 core projects.

Also, Korea is trying to develop basic technologies for precision agriculture, as an alternative way for EFA, and suitable implementation model for Korean situation. Precision agriculture differs from organic agriculture that do not use any chemical agricultural materials, but is expected to settle as a low input sustainable agriculture, because of practical aspect that precision agriculture conducts scientific agriculture using sensors and machinery, which is also suitable for large-sized farming.

In addition, mechanical technology developed or under development for Korean conservation agriculture includes a strip-tillage equipment to reduce soil erosion, a weeding machine and a paper-mulching rice transplanter to prevent and remove weed without herbicides, a strip-tillage rice transplanter to save energy and fertilizer application. And irrigation gates to manage water and water proof materials to reduce water leakage and weed occurrence were also developed. various technologies have been developed and applied to farming for conservation agriculture.

With these continuous development and distribution of policy and technology for conservation agriculture, Korean agriculture is becoming more environmental friendly and sustainable.

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