APPROPRIATE FERTILIZER USE AND FERTILIZATION TECHNOLOGY FOR SUSTAINABLE CROP PRODUCTION

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ABSTRACT

In Japan, the fertilization practices for rice have been greatly improved - from a basal-dominant-application to split-application, and highly efficient and labor-saving fertilization, which helps in coping with the farmers’ rapid aging. The acreage of paddy fields have been successively decreasing under the Japanese government policy. The fertilizer application rate to rice, on the other hand, has also been decreasing for high quality rice production. While not a few Asian countries keep on applying fertilizers several times, this is not as much as the Japanese do in so far as their standardized application to rice. It is still an urgent issue to be solved, to establish the appropriate and sustainable fertilization technology applicable to other Asian countries.

To enhance the sustainable utilization of valuable and limited fertilizer resources, it's important to develop and disseminate various promising technologies for improved fertilizer efficiency, e.g., On-demand basis Nutrient Supply, Full utilization of locally available underutilized organic fertilizer resources.

Key words: efficiency of fertilizer use, nitrogen response, rice, vegetables, analysis of residual nutrient, low-component fertilizer

INTRODUCTION

Climate and soil in Kyushu

Kyushu is located in the south-west of the Japanese archipelago, in which a variety of crops are cultivated all-year round. The climates of Kyushu are classified into six different types, namely, (I) The North: strong winter-monsoon with relatively high snowfall, hence less sunshine; (II) The North-east: a lot of sunny day, hence low rainfall; (III) The West: temperate region surround a bay; (IV) High Elevated Inland: cool and high rainfall; (V) The South: high temperature and a lot of sunshine; and (VI) The Southern Most: warm and small difference in year-temperature.

The climatic types are well reflected in the structured cultivation of winter-vegetables, for instance, in The North; cold-tolerance strawberry and eggplant with low light sensitivity, in The Central; melon and water-melon with medium light sensitivity, and in The South; sweet pepper, kidney beans and string beans with high light sensitivity.

Gray Lowland Soil (GLS) and Andosol are two dominant soils and this occupy 25.4% and 22.3%, respectively of arable soils in Kyushu, and followed by Yellow Soil (13.2%), Grey Soil (10.2%) and Brown Forest Soil (6.2%).

GLS is widely distributed in the northern and central Kyushu, and mainly used for paddy fields. GLS is also widely used for cultivation of various vegetables such as tomato, eggplant, leak and also for the production base of strawberry, melon and water melon. Andosol is widely distributed in the Central and South Kyushu and used for a huge production area of open-field vegetables such as radish, carrot, cabbage, Chinese cabbage, sweet potato and other root crops. Andoson in the high altitudes is used as grassland for the feed of livestock. Phosphorus (P) is an essential fertilizer for crop cultivation in Andosol because of its high adsorption capacity of P. Yellow soil is mainly used for cultivating citrus in orchards.

Use of arable lands

The acreage of Kyushu is 42,190 km², which is equivalent to 11.2% of Japan. The total acreage of Kyushu arable land is 563,800 ha, and it is equivalent to 12.2% of Japan and distributed in flat lowland to high plateau.

The dominant land use is paddy (57.9%),
Fig. 1. Climatic Types in Kyushu

Fig. 2. Average temperature and precipitation
followed by upland, orchard and grassland with a ratio of 28.0%, 11.7%, and 2.5%, respectively. Ratio of paddy and orchard is higher in the northern Kyushu, while the upland becomes dominant in the South.

In view of changes in arable acreage, all the land-uses have been decreasing. In particular, the largest decrease occurred in orchards, followed by upland. Comparing the 1975 and 2008 figures, paddy, upland, orchards and grasslands have decreased by 21.8%, 26.1%, 54.9% and 11.9%, respectively.

**Distinctive features of agricultural production in Kyushu**

**Changes in agricultural outputs**

Fig. 5 shows changes in agricultural outputs (field husbandry + animal husbandry). The agricultural output in Kyushu rapidly increased after 1975 and reached its maximum of 2,034.1 billion in Japanese Yen (JPY) in 1990, and afterwards, gradually decreased to 1,625.6 billion in 2007. The output changes over the past 40 years would be divided into three characteristic Periods. Both of field- and animal husbandry increased greatly during the period of 1965 to 1985, in particular, in the latter half of 1975, when the outputs increased in the field husbandry and animal husbandry by 250% and 200%, respectively. The output in the successive decade did not increase from the previous decade, but maintained a similar level. After 2000, the national agricultural outputs have been decreasing due to climatic disaster, change in people’s dietary pattern, globalization and what not.

Changes in the agricultural output of field husbandry are presented in Fig. 6.

![Soil map of Kyushu](image)

**Fig. 3. Soil map of Kyushu (Kyushu Agri. Exp. Station, 1980)**
Rice, which has been the most important commodity, was purchased by the government and all the rice produced in Japan reached the maximum acreage of cultivation and monetary output for 1930 to 1960. Afterwards, although the cultivation acreage kept on decreasing, the monetary output of rice production reached its maximum by the increased yield per unit area during the period of 1975 to 1985. Along with the westernization and food-diversification, national rice consumption rapidly decreased so that the Japanese government initiated so-called “production adjustment”, followed by an official introduction of “Market-Driven Rice Distribution Concept” in 1997. The change of government rice policy toward “Free Competition in Rice Distribution” brought about a drastic change in the strategy of rice producers from “Increased Yield” to “Improved Quality”. Currently, the rice production in Kyushu shares around 10% of the national production.

Vegetable production started its full swing operations in Kyushu in 1960s to replace barley

Table 1. Changes in acreage of arable land in Kyushu (ha)

<table>
<thead>
<tr>
<th></th>
<th>Total</th>
<th>Paddy</th>
<th>Upland</th>
<th>Orchards</th>
<th>Grasslands</th>
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<tr>
<td></td>
<td>(100)</td>
<td>(54.4)</td>
<td>(25.3)</td>
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<td>417,000</td>
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<td>1995</td>
<td>629,400</td>
<td>356,500</td>
<td>174,400</td>
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</tr>
<tr>
<td></td>
<td>2005</td>
<td>573,600</td>
<td>331,100</td>
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<tr>
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<td>326,300</td>
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<tr>
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<td>(100)</td>
<td>(57.9)</td>
<td>(28.0)</td>
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<td>Kyushu/Japan</td>
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<td>69,500(100)</td>
<td>(54.1)</td>
<td>(36.8)</td>
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</tbody>
</table>

Fig. 5. Changes in agricultural outputs in Kyushu

![Fig. 5. Changes in agricultural outputs in Kyushu](image)
with promising cash crops such as melon, watermelon, tomato, Chinese cabbage, cabbage, potato and tobacco. Thanks to the production adjustment of rice, vegetable production rapidly increased, and its monetary output exceeded that of rice, and reached 400 billion JPY in 1990 to 2000. However, vegetable production started to slightly decrease in a similar manner to rice, due to change in social eating habits (increased eating-out), increased nuclear family, increased imported commodities and so forth. The monetary output of vegetables in Kyushu still shares 18% of the total vegetable production figure in Japan.

Fruit production kept on increasing until 1985 and reached its peak of 181.9 billion JPY, and then decreased up to present with about 120 billion JPY in 2008.

Change in cultivation acreage by commodity in Kyushu

A total of 582,000 ha was planted in 2007, and it was equal to 13.5% of the whole country. In review of every 10 years since 1975, rice planting has been decreasing consistently to less than half of 1975 in 2007. The planting acreages of barley, vegetables, fruits and feed crops have been also decreasing except the first decade (1975 to 1985) by 16.7%, 12.0%, 37.9% and 2.4%, respectively against the output in 1975.

It is one of the distinctive features in Kyushu vegetables production that vegetable production in upland fields are decreasing year by year while the planting acreage of vegetables is increasing in paddy fields. The vegetables cultivated in paddy fields are chiefly tomato, melon, watermelon, eggplant, and strawberry, etc. These vegetables are generally cultivated by covering in some layers of plastic sheets used for protective cultivation like and use of greenhouses. The paddy cultivation protected by the plastic sheets can shorten the growth period of vegetables and produce high quality crops, which can be sold at higher prices. While radish, cabbage, Chinese cabbage, burdock, etc. are called “Heavy Vegetables”. They decreased the production sharply because of factors like aging of farmers, delaying mechanization, decreasing consumption and increasing import of such vegetables.

Changes in fertilization techniques

Changes in the kind- and production of major fertilizers

Fig. 9. shows that changes in production of major fertilizers in Japan for the year 1985 as 100.

In 1985, compound fertilizer production has decreased by 45%, a big dip in figures over the last 20 years. Out of the compound fertilizers, the so-called chemical fertilizers also decreased linearly to 48% by the 1985 production figures. However, various value-added fertilizers such as coated-, liquefied-, slow-releasing, and designated mixed- fertilizers (BB fertilizer) are increasing. This means that the
Table 2. Changes in cultivation acreage by commodity (ha)

<table>
<thead>
<tr>
<th></th>
<th>Rice</th>
<th>Wheat</th>
<th>Vegetables</th>
<th>Fruits</th>
<th>Feed crops</th>
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<td></td>
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<td>55,000</td>
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<td>-45.3%</td>
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</tbody>
</table>

Fig. 7. Relative changes in acreage by commodity (Index; 1975 = 100)
fertilizer industry seems to change their strategy in producing simple chemical fertilizers to more high-valued products.

In view of changes in the acreage of arable land and crops planted, the total acreage of arable land, paddy field, upland field and orchards decreased to 127,700 ha (18%), 55,400 ha (14%), 21,800 ha (12%) and 56,900 ha (41%) over the 20 years between 1985 and 2005. Similarly, the total planting acreage of rice, barley, vegetables, fruits and feed crops in 2005 decreased by 96,600ha (32%), 47,200ha (46%), 15,100ha (16%), 42,700ha (47%), and 24,600ha (17%), respectively, compared to those of 1985. It is noticeable that a decrease in the fertilizer production was much greater than the total planting acreage.

Change in the amount of fertilizer applied to rice is presented in Figure 10. After the fertilizer application to rice reached its maximum in 1985, it decreased almost linearly up to present, and the amount of N, P, K applied per ha considerably decreased by 42.3 kg (49%), 35.0kg (31%), and 38.9kg (39%), respectively. Thus, two factors, namely the decrease in rice planting acreage and the decrease in the fertilizer application per unit area greatly contributed to the decrease in fertilizer production.
Appropriate fertilization technology to rice

Rice is the most important staple crop in Japan, so that a concerted effort has been made to increase rice yield for a long time. Consequently, the yield of brown rice successively increased to over 5t/ha in 1995 from about 4t/ha in 1965. However, the amount of fertilizer applied to rice continuously decreased to 60% of the maximum application in 1975.

Efficient rice production could be attained by various promising technologies and cultural practices such as variety improvement, protection from various rice pests, paddy field consolidation, increased soil fertility, improved fertilization technique, water management and the like. In fertilization technology, in particular, the emphasis on basal dressing in 1960s was replaced by dominant fertilization at the later growth stage of the rice crop cycle. After 1975, an innovative fertilization technique, which provided for a proper amount of fertilizers by measuring the leaf color of rice plant (as the growth stage of the plant proceeded), was developed. In view of rapid aging of rice farmers, a variety of highly sophisticated technology in efficient and labor-saving fertilization to rice has been developed. The development of nutrient releasing-controlled fertilizers (NRCF) such as slow-releasing- and coated-fertilizers was along with the same lines of the said concept.
Some promising fertilization technologies are presented below

**Side-application**

At the transplanting time, localized basal application is conducted at 2~6cm apart from rice plant at a depth of 3~5cm to enhance utilization efficiency of the fertilizer. A transplanting machine exclusive to the side-fertilization has been developed and becomes popular, in particular, in the areas, which a lot of large-scale farmers are actively involved in rice production. This technology can, not only save the basal fertilizer by 20~30%, but was also found to be effective for labor-saving and anti-water pollution.

**One-shot basal application**

Thanks to the development of various NRCF (linear-type releasing, sigmoid-type releasing etc.), it becomes possible to provide a proper amount of nutrient with rice plant at its desired time. This method can save some 10~20% of the total fertilizer applied.

**One-shot seedling-box application**

All the nutrients necessary for the whole growth stage of rice plant are applied by one-shot application of Sigmoid-type nutrient-releasing controlled fertilizer to a Seedling box at the time of seeding. This method is considered to be more labor-saving and environment friendly form of fertilization. The use of NRCF is well-adopted by Kyushu farmers and some 30% of rice farms are using this high-value fertilizer.

Currently in Japan, the first priority is placed on the quality rather than the quantity of rice produced. Since rice varieties developed for high quality produce are generally easy to fall down before its harvest, it is highly recommended to reduce the basal dressing, in particular, nitrogen. There is a negative correlation between the rice taste and protein content in rice grain, so that the N application in the late growth stage of rice plant is recommended to be reduced to as low as possible.

The application of N, P₂O₅, and K₂O in 2008 was considerably decreased to 55%, 70% and 53%, respectively compared to the 1985 applied. It is noticeable that recent rice varieties would like to absorb and accumulate about 100kgN, 45kgP₂O₅, 95kgK₂O per ha in its upper parts (grain, leaf and shoot combined), in case the yield of brown rice grain is supposed to be 5000kg/ha. Thus, the nutrients absorption by rice plant would be lower than the nutrients applied.

On the other hand, in view of worldwide fertilizer application, there are quite a few countries which apply several times as much as the Japanese standardized application, so that it is a matter of urgency to improve fertilization technology based on the analysis of yield component factors of rice plant.

**Appropriate fertilization technology to vegetables**

The major vegetables produced in Kyushu are: (in descending order), strawberry; tomato; cucumber; potato; melon; leak; eggplant; bell pepper(sweet pepper); watermelon; radish and more recently, asparagus. Leak(green onion), onion and okra are also increasing. Although the cultivation acreage of vegetables in Kyushu is only 14% of the whole country, its monetary output can reach some 20% of the national total figure. Nearly 60% of the produce in Kyushu is shipped to such urban cities as Tokyo and Osaka. Kyushu can ship a variety of vegetables almost all the year round.

Since there is tremendous number of vegetables cultivated in Kyushu, it is a rational approach for the decision of appropriate fertilization to each vegetable, to categorize vegetables based upon their nutrient absorption-pattern (Table 3). Based on the nutrient absorption pattern of vegetables, first of all, fundamental fertilization strategy toward some vegetable group is made (based-accentuated fertilization, basal-top fertilization, top-accentuated fertilization etc.).

Next, the total fertilizer application is decided based on nutrients absorbed by each vegetable for the targeted yield (e.g. how much N, P and K is absorbed by tomato to obtain the yield of 100kg/10a), and finally, a proper fertilizer type is decided. It is also recommended that the amount of fertilizer applied is adjusted in terms of soil nutrients. The nutrients are contained in compost and manure applied, together with the said fertilizer. However, it is a more common practice that field experiments are conducted to optimize the amount of fertilizer applied to each vegetable after the fertilization strategy is decided via the above-mentioned procedure. These experiments are, in particular, important in case the same vegetables are cultivated in different seasons, and the amount of fertilizers, in fact, should be increased under a low temperature condition.
In the major vegetable production areas in Japan, a decrease in the yield of major vegetables and outbreak of various diseases have been brought about by the interval of 7 to 15 years due to so-called continuous cultivation damage, so that the production areas should be periodically moved to other areas. In the paddy-basis vegetable production areas in Kyushu (called as Paddy-Horticulture Areas), however, it has been possible to cultivate a variety of vegetables continuously over 30 to 40 years without any serious damage. The advantages of the Paddy-Horticulture are:

1) Provide sustainable N supply from paddy soil of increased fertility during a submerged period;
2) Keep a proper regime of soil water for enhanced growth of vegetables with adequate drainage management;
3) Suppress the continuous cultivation damages by a repeat of soil oxidation and reduction;
4) Left-over of the excess fertilizer in soil during the cultivation of vegetables can be absorbed by successive rice plant and/or dissolved in submerged water, and cannot be accumulated in the soil. This Paddy-Horticulture rotation practices are also recommended by AVRDC to minimize continuous cropping hazard of horticultural crops.

However, there are many key techniques for
the successful application of Paddy-Horticulture systems. First, the proper countermeasures against Mn excess should be taken for newly converted paddy from upland field of Andosol rich in Mn. The effective soil management for the Mn excess is a proper drainage to avoid heavy soil reduction and liming to improve soil acidity.

In the cultivation of Cucumis, farmers have concentrated on the production of high valued big fruits in terms of excess application of fertilizer and organic matter, using strong and vigorous rootstock for grafting, forced pruning, etc. This led to imbalance in nutrient metabolism and relevant minerals, resulting in serious physiological disorder of Cucumis crops to fermented fruits.

Due to increased planting of vegetables per unit area, a lot of nitrates could not be absorbed and are left in soil. The accumulated nitrate are moved to the lower soil layers by rainfall irrigation and forced submergence of surface soil and further reach underground water pool and polluted there.

Fig. 13. shows the trace of nitrate nitrogen movement in the soil profile after harvest by different cropping patterns. In the system of continued protective cultivation (House crop - House crop), medium level of nitrate nitrogen is almost evenly distributed in the whole profile, while protective cultivation-open field cultivation rotation (House crop - Open crop), a high level of nitrate nitrogen is moved down to the lower soil layers. In the continued open field cultivation (Open crop – Open crop), the two peaks of high nitrate nitrogen can be observed at the top layer and in the profile below 100 cm from the surface, due to top fertilizer dressing and its moving-down to the lower layers, respectively. In the rotation of protective cultivation with rice (House crop – Rice), the downward-movement of the nitrate nitrogen left in the soil is likely to be enhanced by the introduction of rice into the crop rotation. It should be noted that a sizable amount of fertilizer applied to vegetables is left in the soil without being fully utilized by crops, and the repeated cultivation of vegetables enhances leaching of the fertilizers left in the top layer to the lower layers. This may finally reach a groundwater pool and pollute the nearby surroundings.

Fertilization of vegetables in Kyushu was chiefly initiated with a combination of a mixed fertilizer and a single-component fertilizer for basal application and top dressing, respectively. The basal dressing was gradually replaced by micro-organism through the use of degradable slow-releasing fertilizer. Recently, coated fertilizer (nutrient-releasing rate- and amount-controlled fertilizer) is dominantly used by farmers because of the viewpoint of labor-saving, fertilizer efficiency and environmental friendliness. Application of organic matter such as compost is commonly used for improvement of soil and its chemical and physical
properties. The organic material application is also important to increase soil fertility in a sustainable manner, so that the bio-available nutrients from fertilizer, soil organic materials should be properly evaluated at the relevant growth stages and adjust to the amount of fertilizer applied based upon the vegetable’s demand. In addition, farmers try to optimize the nutrition status of vegetables by applying liquid fertilizers as top dressing based on its periodical leaf diagnosis.

Next, a couple promising fertilization technologies for vegetable production are introduced.

**ONE-SHOT BASAL APPLICATION**

It is most important whether the amount and rate of nutrients released from the fertilizer applied to vegetables can be controlled. A variety of application techniques have been developed according to the kind of vegetables such as one-shot basal application, band-application, ditch application, seedling-pot application and seedling-cell application. These application techniques and varied release-period coated fertilizers are combined to cope with various growth duration of vegetables from short to relatively long ones such as eggplant, bell pepper, tomato and strawberry.

For instance, fertilization can be reduced by 30% in the protective cultivation of tomato in summer and autumn by applying the coated fertilizer in the vicinity of tomato roots, while in the eggplant, during the cultivation in autumn to spring, a sigmoidal-nutrient releasing coated fertilizer could not only reduce the fertilizer by 20%, but could also decrease laborious works of top dressing considerably. It has also been established that a very promising fertilization technique of one-shot basal application for strawberry is effective by using the sigmoidal coated fertilizer.

**TRANSPLANTING-HOLE APPLICATION**

It is remarkable time- and labor saving fertilization technique to apply organic fertilizer containing low nutrients or coated fertilizer into the transplanting holes. Conventional chemical fertilizers such as ammonium sulphate and urea cannot be used for this purpose because the highly concentrated ammonium nitrogen or nitrate nitrogen released from the said fertilizers may cause serious root damages due to their high solubility in the soil solution. This technique came to be widely used with development of sophisticated coated fertilizers.

**WAITING FERTILIZATION**

Organic- and/or chemical fertilizers are applied at the edge of cultivation beds in advance to avoid direct contact between vegetable roots and fertilizer. In other words, the fertilizer applied in advance is waiting for root elongation of vegetables.
ONE-FERTILIZATION TO TWO CROPS UNDER MULCH

In the cropping system of lettuce-cabbage from winter to spring, fertilization is conducted only to lettuce. One-shot application for two crops is made by the combination of coated fertilizer and organic- and chemical fertilizer, and this can save the fertilization by 25%.

DITCH APPLICATION

For long-term tomato cultivation, the ditch with 45cm in width and 85cm in depth is dug and fully matured organic matter and half of coated fertilizer necessary for tomato growth are placed in the ditch. The remaining half is applied using the broadcast method.

FERTILIZATION BY LIQUID FERTILIZER

Recently, fertilization by liquid fertilizer throughout the growth period becomes popular. Although the initial investment on some facility and instruments are necessary, this technology provides a lot of advantages. Producers experience a drastic decrease in growth damage and disease outburst by minimizing excess fertilization, ultimate labor-saving by automated operation, and an increased yield of high quality vegetables. Currently, this system comes to be more sophisticated for more stable production of vegetables by the combination with a real-time nutrient diagnosis technology. However, even if the sophisticated technology is developed for the precision analysis and adequate diagnosis information, the final decision on the best diagnosis for the worst should be made by farmer’s indispensable experience and judgment.

Future perspective of fertilization and fertilizer for vegetables

As previously described, the main targets of vegetable production in Kyushu has changed with time and various stakeholder’s demand for fertilizer efficiency, stable and sustainable production with high quality crops, labor-saving, environment friendliness, and cost performance. Toward this direction, the amount of fertilizer applied has been continuously decreased over the last several decades as presented in Fig. 15.

However, the highest yield is still the most
important target for producer’s managerial strategy, and many fertilizer residues (nutrients) have been accumulated in the soil of vegetable production field. In Kyushu, there are 34.2% of the total areas of glass- and vinyl houses used for protective cultivation and this is 26.9% of the total acreage planted to vegetables in Japan. The vegetable cultivated field has a tendency towards the increased application of fertilizer, hence the accumulation of fertilizer residues unused by vegetables because of its long duration of cultivation and its increased frequency of planting on the same soil.

**DIFFERENCE IN THE RESPONSE OF VEGETABLES AND RICE PLANT TO FERTILIZATION**

The authors attempted to elucidate the characteristics of nitrogen utilization pattern by vegetables in comparison with Gramineous by using a computer simulation model developed by D.J. Greenwood. In this simulation model, an increase in the N absorbed by crop, an increase in crop dry weight, and changes in the N mineralized in soil can be estimated on a daily basis. The relation between the amount of N absorbed and the N applied obtained through a field experiment was well reproduced by this simulation model. The N absorption by Gramineous crops increased linearly with the amount of N applied, as long as the supply-demand of N is well balanced (an apparent recovery of N was kept constant), but the N demand by crop exceeded the N supply from soil and fertilizer, an apparent recovery of N gradually decreased.

While both the N absorption and dry weight of vegetables increased through the addition of N application, it reached its maximum at nearly upper limit of the whole N application. However, an
apparent recovery of N almost linearly decreased by increasing the N applied. The maximum yield is obtained at relatively low level of N application indicated as arrows in Fig. 18.

There are various relevant factors to explain the difference between Gramineous and vegetables in the N response to the N applied. However, these complicated problems could be solved in terms of introduction of a key parameter, Km which is considered to be the amount of mineral N in soil when N absorption ratio is equivalent to half of the theoretical maximum value. In case Km is set at 10 kg N/ha, the relation between the N absorption by crops and apparent recovery of N is same as that for Gramineous, while the relation becomes similar to that of vegetables for Km > 400 kg/ha or above.

What is the difference in the N responses between vegetables and that of Gramineous? It is more likely to stem from the difference in their root systems. The root of Gramineous starts developing from an early stage of growth, and keeps on developing widely and densely. In contrast to Gramineous, the development of vegetable roots is initially very slow and limited in the vicinity of the transplanting hole. Even in the late growth stage, the roots can be developed poorly and less-densely only in the surface layers of the soil. The root length of some vegetables at harvest 2.4 km/m², 1.8 km/m², and 11.9 km/m² for lettuce, onion, and cauliflower, respectively, while that of wheat at early growth stage can reach as long as 8 km/m².

The Km value is decreasing in soil as the growth stage of crop proceeds because the crop can absorb mineral N from a wide area of soil layers with elongating its root system widely and densely throughout soil profile. Burns reported that the
crop exposed by N deficient environment at initial period of growth, the crop yield was drastically decreased even if the N status would be improved afterwards. It is therefore very important to meet crop’s demand for N at the early growth stage when the soil Km is high. A broadcasting application of fertilizer is not recommendable for vegetables, in particular, at the early period of growth. Instead, it is highly recommended to apply a small amount of N fertilizer to the place just below where the where the seeding/seedlings are transplanted, and the broadcasting of fertilizer as top dressing should be made after the vegetable roots are sufficiently developed at the latter growth stage.

For the successful fertilization in the vicinity of vegetable roots, it is a key technique to skillfully avoid root damage due to the direct contact between concentrated N released from fertilizer and the root. As already repeatedly explained, coated fertilizer (N release controlled fertilizer) is one of the best solutions, but well- matured organic matter and various promising fertilization techniques described before can provide a good guidance for appropriate fertilization to vegetables under different circumstances.

CONCLUSION

Zennoh’s efforts toward optimizing fertilization for sustainable production

Fertilizer is one of the most important supplies for agricultural production. However, Japan is almost fully dependent on foreign countries for the fertilizer raw materials. Although Zennoh is responsible for nearly 60% of fertilizer’s demand in Japan, as of 2008, the demand for the fertilizer is decreasing every year. There are a variety of factors for the decreasing demand of fertilizer, and the followings are major reasons for the decreased demand; 1) government policy of decreased rice production; decreased acreage of rice cultivation due to farmers' aging; 2) increased popularity of labor-saving functional fertilizer; and 3) environment friendlier fertilization.

However, the worldwide demand toward fertilizer is considerably increasing, and consequently, a great increase in the fertilizer price was brought about in 2008. In view of the current fertilizer situation, Zennoh strongly requested to provide farmers with a stable and low-cost fertilizer and a variety of agricultural supplies. To cope with the farmer’s demand, Zennoh makes great efforts to strengthen and smoother import of raw materials from foreign countries and to promote developing high quality- and low cost- fertilizers which was designed from soil nutritional condition, under own brand of JA group (ex. PK-Save).

According to Zennoh’s nationwide soil analysis, there are quite a few arable soils accumulated with excess fertilizer residues. The excess residues not only disturb soil-nutrient balance, hence crop healthy growth, but also provide various stakeholders with a remarkable opportunity to consider an effective use of under-utilized resources accumulated in arable soils.

Fig. 20. Strategy for improved cost performance based on soil diagnosis
To cope with people’s concern about resource-effective and cost-effective soil and fertilizer policy, the new nationwide campaign on the so-called “Appropriate Fertilization and Increased Soil Fertility” has been launched. The campaign slogan has been changed with time from “Improved Fertilization-Increased Soil Fertility for High Yield”, to “Improved Fertilization-Increased Soil Fertility for High Quality product”, and “Improved Fertilization-Increased Soil Fertility for Alleviation of Environmental Land”, and finally to “Improved Fertilization-Increased Soil fertility for Cost-Effective Agriculture”.

Zennoh is now working on a national campaign using a three-step approach; 1) Understanding the current status of soil fertility for the targeted field based upon soil analysis; 2) Making out the prescription as to on-what and how-to improve the soil fertility of the targeted field; and 3) Optimizing the soil nutrient status for targeted vegetables by adjusting the amount of fertilizer applied and changing fertilizer to more suitable ones and what not.

Zennoh established newly nine soil analysis centers all over Japan to cope with a variety of analytical and diagnostic problems, and its guidance and extension. The nine analytical centers are installed with highly sophisticated and advanced instruments and facilities for soil- and plant-analysis and data management. The analytical data thus collected nationwide are bulk-managed.

Training workshops on enhancing human capacity building are periodically held to raise the JA-staff to provide farmers with a comprehensive guidance on appropriate fertilization based upon the prescription as a result of soil analysis.

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