FERTILIZER RECOMMENDATIONS FOR SUSTAINABLE PRODUCTION OF ORCHARD FRUIT IN THE SOUTH OF VIETNAM

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ABSTRACT

Vietnam possesses favorable conditions for the development of fruit crops. In 2000, fruit crops were planted on 541,000 hectares, producing a total of 4.9 million mt of fruit. Most tropical fruits are grown in the southern part of Vietnam. They include durian, rambutan, mangosteen, mango, dragonfruit, and star apple (carambola). Seventy percent of fruit production is in the south, concentrated in two main regions: the Mekong Delta and the southeast. The southeastern region is hilly, and most of its soils are Acrisols, Ferrisols or Alisols. Among the limiting nutrient factors are a low organic matter content, a low pH and a low level of calcium, magnesium and potassium. In the Mekong Delta, most orchard soils are alluvial (Fluvisols and Gleysols). Limiting nutrient factors are low levels of calcium, magnesium and available phosphorus, and high levels of free aluminum and iron. Fertilizer recommendations for fruit growers in the two regions focus on overcoming these limiting factors.

FRUIT PRODUCTION IN VIETNAM

Vietnam possesses favorable conditions for the development of fruit production. It has a diversity of soils, a suitable climate, and abundant water and labor. Fruit crops, with their enormous genetic variability, can be grown in a wide range of climatic conditions. They promote the efficient use of labor, especially during the off season for rice cultivation. At this time the trees are dormant, and training and pruning can be carried out. The relatively high price of fruit gives a good economic return to growers.

For centuries, Vietnamese farmers have been growing fruit crops in their backyards. They have been selecting high-quality fruit varieties over many generations. With the improvement of propagation techniques, and the implementation of government-funded programs to promote high-quality varieties, a wide range of species, varieties and lines are now available to fruit growers.

The area planted in fruits in Vietnam has been steadily expanding in recent years. The area under fruit crops reached 541,000 hectares in 2000, with a total yield of 4.9 million mt, compared to only 346,400 hectares and 2.7 million mt in 1995. In the year 2010, the target is to achieve one million hectares of orchards.

The climate in the north of Vietnam is quite different from that of the south. The north part is subtropical with four distinct seasons. The south is much warmer and has only two seasons, the dry and the wet. Presently, the area planted in fruit trees in the south part is 70% of the whole fruit-growing area of Vietnam. The south is also the producer of tropical fruits for the whole country. The most important tropical fruits are durian, rambutan, mangosteen, mango, dragonfruit and star apple (carambola). Some of these have good export potential.

The Mekong Delta is the main area of tropical fruit production. Most of the land used for fruit trees in the Mekong Delta is lowland alluvial plain, in contrast to the orchards in other parts of the south which are almost all on hilly land.

Keywords: fertilization, nutrient balance, orchard soils, tropical fruits, Vietnam

SOIL FERTILITY OF FRUIT ORCHARDS IN SOUTHERN VIETNAM

Hilly land

Most of Vietnam is hilly land with soils which belong to the groups of Acrisols, Ferrisols and Alisols (Siem 1997). They have certain characteristics which should be taken into account when the land is used for fruit orchards.

Organic matter content

The soils are often low in organic matter and humus reserves. Most of the organic materials are in free forms and in loose combination with sesquioxides, so are easily washed away. The soil organic matter content is related to most of the soil fertility indices. Loss of organic matter will lead to the collapse of soil physical properties, the water balance and nutrient reserves. To remedy the situation, organic matter should be applied to the soil at a rate of around 10 mt/ha/year.

Absorption capacity

The absorption capacity is usually low, as is the ability to retain nutrients. As a result, fertilizers are quickly leached from the soil. Fifteen years after the land has been cleared, the CEC value drops to 50% of its original level (Siem 1997). The absorption capacity is also characterized by a low alkaline saturation point, while the levels of lime and magnesium are quite low.

This contributes to a low fertilizer efficiency (just 40-60% for nitrogen, 40-50% for potassium, and less than 30% for phosphorus) (Siem 1997). Therefore, fertilizer should be applied in small amounts in several splits. It is also necessary to add lime and magnesium to any fertilizer applied, to increase the volume and absorption capacity.

The dominant minerals in the soil solution complex are clays with a very low absorption capacity. It is not possible to change the mineral composition, so the most effective way to improve the soil absorption capacity is by applying both organic and chemical fertilizers in combination.

Leaching

Nitrogen and other elements such as sodium (Na), calcium (Ca), potassium (K) phosphorus (P) and magnesium (Mg) are the first to be washed away. The order is Na-K-N-Ca-Mg-P. An increase in hydrolic acidity and the presence of free aluminum (Al) are very common. An effective way of regulating the acidity and increasing the capacity to absorb alkaline materials is to apply neutral fertilizers, alkaline fertilizers or fertilizers in which all the surplus acid is already neutralized (Siem 1997).

Low potassium content

Almost all of the fruit orchards in the southeast and the Central Highlands have red soils or grey soils. Kaolinite is the dominant clay mineral in these soils, and has a marked effect on the CEC of the soil. As well as a low CEC, these soils also have a very low potassium (K) content (Sat and Binh 1997). Moreover, because K is an active element, it is depleted very quickly during cultivation.

Many kinds of fruit trees have a high demand for K, especially during the stage of fruit development. K becomes a limiting factor in both the yield and quality of fruit production, especially in areas with impoverished grey, red-yellow sandy or basaltic soils.

Fertilizer applications to fruit orchards now generally have an unbalanced nutrient content. Less K is applied than is needed by the tree. Potassium deficiency is especially marked in tropical fruit crops grown in basaltic soils with a low natural level of K.

The Mekong delta

Phosphorus fixation

While fruit orchards located in hilly land have the problem of a low potassium level in the soil, the soils down in the plains of the Mekong delta region, where a large area is planted in fruit crops, often have the problem of phosphorus fixation.

A large part of the land growing fruit crops in the Mekong delta has acid soils which have a low level of calcium (Ca^{++}) and

magnesium (Mg^{++}), and a low alkaline saturation point. These acid soils are rich in sesquiosides, and have high levels of free aluminum (Al^{+++}) iron (Fe^{+++}). Because of these characteristics, the phosphate is mostly insoluble, while calcium phosphate is present only in small amounts. Phosphorus usually exists in such soils in the form of aluminum oxide ($AlPO_4$) or iron oxide ($FePO_4$). Little of it is active since most of it is fixed. The fixation is severe in some soils with a high clay content (Siem 1997).

To reduce phosphorus fixation, we can increase the pH, the silica (SiO_2) content, or the level of alkaline metals and organic substances. Applications of organic materials are the most feasible, for they have a large surface area, are a source of negative colloids, and have a weak affinity to phosphorus.

Phosphorus is the limiting factor for fruit production, not only in the Mekong Delta but also in the hilly land of the southeast region and the Central Highlands. Soils in hilly areas have many unfavorable characteristics for the release of phosphorus, such as a low pH, a low level of alkaline cations, low absorption capacity and alkaline saturation point, high levels of aluminum and iron, and a dominance of kaolinite. All these cause phosphorus deficiency in fruit crops.

Imbalance of nutrients

Another problem is the imbalance of nutrients in the fertilizer applied by a large proportion of fruit growers. Growers often use a single rather than a compound fertilizer. They tend to apply much more nitrogen in relation to crop needs, compared to potassium and phosphorus. These old fertilization habits, which stress the use of nitrogen while neglecting phosphorus, potassium, lime and micronutrients, must be changed.

The proportion of the applied nutrients nitrogen:phosphate (P_2O_5):potassium oxide (K_2O) used in Vietnam in 1992 was 100:29:7. This can be compared to the average proportion world-wide of 100:49:38 (Hien 1997).

Concerning the physiology of nutrient uptake, phosphorus works well when applied together with most major elements, including nitrogen, potassium, calcium and magnesium. It does not work well when applied together with sulfur and some macronutrients. Therefore, increasing the efficiency of phosphorous fertilizer requires a good combination with other major nutrients.

The application of phosphorus with nitrogen, potash, lime and magnesium significantly contributes to the development of the roots, the release of soil phosphorus, and an increase in the phosphorus absorption capacity of the tree (Siem 1997).

Various formulations of NPK fertilizers help fruit growers achieve balanced fertilization. In recent years, NPK fertilizers have been manufactured in Vietnam, rather than imported. This makes it easier to regulate the proportions of the major elements in accordance with the needs of crops, soils and the different stages of development of fruit crops. It also helps to avoid a deficiency or surplus which may be harmful to the environment. It also cuts the costs of transport and labor, and helps promote fertilizer efficiency.

SOME POINTS TO CONSIDER IN FERTILIZER MANAGEMENT

Status of fruit crop development

- *Fruit trees are perennial.* As fruit trees are perennial crops, they take up nutrients year after year from the soil zone around the roots. If fertilizers are not applied every year, the soil will be poor in nutrients, and the productivity and quality of the trees will be badly affected.
- *Tree age and tree size*. More nutrients are needed as the tree develops in age and size.
- *Tree vigor*. Weaker trees with less vigor need more nutrients to help them recover.
- *Last season's yield.* The higher the yield in the previous season, the more nutrients are needed.

Soil status of fruit orchards

Desirable chemical characteristics

Soils of fruit orchards should contain reasonable levels of nutrients, and be capable of supplying these to fruit crops. The content of different essential nutrients (total and available/exchangeable forms) in the soil of fruit orchards decides what quantity of different

fertilizers should be added.

A good orchard soil should have:

- High cation exchange capacity;
- Good buffering capacity and a stable pH;
- Low electric conductivity (CEC); *and*,
- A low and stable C/N in the organic matter content and the organic materials applied.

Physical properties

A good orchard soil should have:

- High moisture-holding capacity, to store available water and supply it when needed by the trees,
- Low bulk density and good aeration;
- High hydraulic conductivity for good drainage; *and*,
- Good anchorage and stability for the plant.

It should also be highly porous, with minimum variation in volume by shrinkage when it dries.

Some special precautions for fruit orchards in the Mekong delta

Growers should ensure that their orchards have good drainage in the rainy season. In the Mekong delta, fruit trees are generally grown in alluvial plains. Where land is at a low level, there is often an acid sulfate layer under the surface soil. Orchards far from the bank of the river, where the soil surface is lower, should grow their trees on raised beds. Such beds raise the level of the soil surface and promote root development, while the areas between the raised beds make channels for good drainage. Dykes around orchards are also needed, to protect the orchards from annual flood waters.

Land also needs to be raised in other parts of the Mekong delta, to provide a thicker topsoil layer for the development of the root system, and to increase the vigor and productivity of the trees. Raised beds separated by channels also help to give orchards good drainage.

When making the bed, growers should avoid moving the acid sulfate layer up into the topsoil where the trees will be growing. The acid sulfate layer must be in the lower part of the bed, below the surface soil layer. Furthermore, the surface soil layer should be raised up in the center of the bed, where the seedling will be placed, while the acid sulfate soil layer should be kept to the sides. The acids in the lower soil will be gradually washed out ('eluted'), so that the pH will slowly rise.

ORGANIC FERTILIZERS

Organic fertilizers may be based on plant materials, livestock manure, or both. Besides supplying nutrients to the soil, organic fertilizers also help to improve the soil structure. However, only a small part of the organic nutrients can be absorbed immediately by plants. The rest, still in a crude form, needs time to be decomposed by microorganisms living in the soil. Therefore, it is difficult to estimate the exact level of nutrients supplied to crops by organic fertilizer, because this depends on many factors.

The application of organic fertilizers during heavy rain should be avoided, because nutrients will be leached down to lower layers of soil, beyond the reach of most of the plant roots, and will be wasted.

The quantity of organic fertilizers applied to fruit trees depends on the species and size of the tree. It is common to apply 10-20 kg per tree each year in both the Mekong delta and the southeast region. Combining organic fertilizer with inorganic fertilizers will help to increase the efficiency of inorganic fertilizers and increase the yield and the quality of fruit (Chau 1997). Chicken manure and processed urban wastes applied as an organic fertilizer to durian (*Durio zibethinus*) helped improve tree vigor, increased productivity and decreased the severity of *Phytophthora* disease compared to the untreated control (Tri and Binh 2002).

FOLIAR FERTILIZERS

If leaf analysis or physical symptoms indicate a fertilizer deficiency status, fertilizing the trees with a foliar fertilizer is a quick way of improving the situation. Macronutrients are generally applied to the soil. However, when problems of dilution, penetration and fixation of a nutrient exist, foliar applications may be more effective. Foliar applications are also recommended when there is an extreme nutrient imbalance. The most important use of foliar sprays, however, has been in micronutrient applications.

In the past, fruit growers in the southern part of Vietnam used to apply potassium nitrate (KNO_3) as a foliar fertilizer to mango trees to adjust the blooming time. Many types of foliar fertilizers are now being manufactured in Vietnam for different stages of fruit crop development, usually to stimulate blooming or prevent fruit drop, and help to increase fruit size and fruit quality.

The application of foliar fertilizers to durian and mango helps to boost their productivity. Foliar fertilizers containing a high level of potassium and phosphorus but no nitrogen are usually sprayed 1-2 months before blooming, to accelerate the maturing of leaves, prevent the development of new leaves and stimulate blooming.

After durian and mango pass the blooming stage, some small fruits drop and the size of the remaining fruit increases rapidly. The fruit crop at this time requires a sufficient and timely nutrient supply. The application of a foliar fertilizer with a proper nutrient formula, in addition to soil fertilization, gives the best results. Growers should spray 4-6 times at intervals of one week after blooming, in order to increase the size and quality of fruit (Chau 1997).

PLANT ANALYSIS

There are several methods of assessing the fertilizer requirements of fruit trees. These include visible symptoms of deficiencies or toxicities, soil analysis, plant analysis and experimental field trials. Plant analysis has been carried out recently in Vietnam for some high-value fruit trees such as citrus, durian, mangosteen and longan.

Standardized techniques have been applied to sampling, and it is possible to apply the standards developed under particular soil and climatic conditions to other locations with reasonable assurance. This helps extension staff to give advice immediately on what kind of nutrients should be applied to orchards. However, because laboratory facilities are limited, plant analysis is not yet widely used.

NUTRIENT SUPPLY ACCORDING TO THE DEVELOPMENTAL STAGE OF THE TREES

Some tropical fruit trees such as durian, mangosteen and rambutan require different proportions of N, P, and K as the trees reach different developmental stages. There are four main stages: before blooming, fruit set, fruit development and post-harvest.

Stage before blooming

At 1-2 months before blooming, fertilizer needs to be applied with the aim of:

- Helping existing leaves to mature;
- Preventing the appearance of new leaves, thus avoiding competition for nutrients; *and*,
- Enhancing flower initiation.

Fertilizers applied to the soil at this stage should have a high P content, a high K content and a low N content. The proportion of $N:P_2O_5:K_2O$ may be 1:3:2 or 1:3:3 (Chau 1997).

In addition to fertilizing the soil, a foliar fertilizer with no N, very high P and a high K content should be sprayed. Boron should also be applied. Besides using fertilizer, creating a long, dry period just after the completion of leaf development to limit the vegetative growth of the tree, and then applying plenty of irrigation water, also helps to enhance flower initiation.

Fruit setting stage

At this stage, the tree needs to receive equal amounts of N, P_2O_5 and K_2O. If nutrients cannot be supplied in time, some immature fruits will drop. Foliar fertilizers which do not contain N or GA3 should also be sprayed (Chau 1997). The N and GA3 should not be included in the foliar spray because they can lead to the development of new leaves. These will compete with the young fruit for nutrients.

Fruit development stage

To improve the size and general quality of the fruit, fertilizer should be applied to the soil as well as in the form of a foliar spray. NPK fertilizer ($N:P_2O_5:K_2O$ in the proportion 1:1:1.5), should be applied to the soil. The foliar spray should have a high K content. Calcium nitrate is also recommended at this stage, as the calcium helps to increase the firmness of the flesh and the color of the fruit, as well as prolonging the storage life after harvest. Foliar fertilizer should be applied 4-5 times at this stage (Chau 1997).

Stage after harvest

Immediately after the harvest, the following tasks must be done to prepare the tree for healthy regrowth.

- Branches should be trimmed. Those affected by pests and diseases should be removed.
- The soil should be turned: N:P_2O_5:K_2O fertilizer should be applied in a proportion of 1:1:1, plus organic fertilizer at the rate of 10-20 kg/tree, according to tree size.

If the development of new leaves is poor, or the previous harvest was a good one, increased nitrogen should be in the fertilizer applied to the soil, as well as in foliar fertilizers. Irrigating the trees frequently to support the development of new leaves is also important.

FERTILIZER FOR SOME MAJOR FRUIT CROPS IN SOUTHERN VIETNAM

Vietnam is considered one of the most important sources of germplasm of tropical fruit trees. Although it has a wide range of fruit kinds and varieties, only a few of these are of major economic importance.

Many growers do not know how to fertilize their fruit trees. Data from a survey by the Southern Fruit Research Institute (SOFRI) on fertilization of fruit orchards in the Mekong delta revealed that 58% of growers in this region did not know how to choose appropriate fertilizers for their soil, while 32% of growers did not understand the effect of the various nutrients on the growth and development of the crop. Research on fertilizer recommendations for fruit trees have been conducted over past decade by SOFRI and several universities in the south of Vietnam, but more research is still needed. We also need to do more to extend information about recommendations so that it reaches all the growers.

In deciding on the correct rate of fertilizer to recommend, it is necessary to take into account two objectives: maximizing the response to fertilizer (in economic terms) of the fruit trees to which the fertilizer is applied, and the improvement, or at least maintenance, of soil fertility over a period of years.

With the rapid growth in the use of fertilizers all over the world, and the considerable rise in prices over the years, it is essential to utilize fertilizer in the most productive and profitable way. Efficient utilization of fertilizer depends on using the correct doses of nutrients in relation to the needs of the fruit trees and the soil, and on applying them in the best manner at the right time.

Recommendations for some major fruit trees in southern Vietnam are shown below.

Durian

Durian is grown in several parts of the southeast region and Mekong delta. The area planted in durian has been expanding steadily in recent years. This increase in durian production is mainly because of the high income growers can earn from it. While durian trees in old orchards are a range of clones and do not have uniform fruits, growers in new orchards often use improved cultivars which have small seeds, a higher proportion of edible pulp and a better flavor.

Durian trees are usually grown at a density of 100-150 trees per hectare. Basic fertilization with organic manure (usually composted on the farm) is at the rate of 10-15 kg/tree. For young trees during the first few years, the recommended dose is N: P_2O_5:K_2O: MgO in a proportion of 18:11:5:3 (or 15:15:6:4 in the Mekong delta), at a rate of 0.7 kg of NPK fertilizer per tree per year. This rate increases steadily to 3.5 kg/tree in the fourth year, spread over 3-5 applications per year (Chau 1997). In the southeast region, more potassium should be applied. During the fruit-bearing years, the level of fertilizer applied should be adjusted depending on the vigor and size of the tree, while the proportion of nutrients should be adjusted according to the developmental stage of the tree (see page 5 above).

For durian trees growing in orchards along the Saigon river, during their fruit bearing years (i.e. when they are at least six years old), the recommended fertilizer rate is 800 g N + 400 g P_2O_5 + 400 g K_2O + 100 g MgO plus 40 kg compost per tree per year (Tan and Chau 2000). This fertilizer is divided into three applications. The first (1/2 N + ¼ P_2O_5 + ¼ K_2O +1/2 MgO and all the compost) is applied straight after the harvest. The second (1/4 N + 1/2 P_2O_5 + ¼ K_2O) is applied

before blooming and the third (1/4 N + ¼ P_2O_5 + 1/2 K_2O +1/2 MgO) when the young fruit is beginning to develop.

In recent years, the main problem in durian production has been disease caused by *Phytophthora palmivora*, a soil-born fungus. Tri *et al.* (2001) reported that the application of composted chicken manure and city waste helped to reduce the incidence and severity of this disease.

Dragon fruit

The two main areas for the production of dragon fruit are Binh Thuan (in the southeast region) and Long An (in the Mekong delta). The same cultivar is used in both places, but the cultivation practices are different. Concrete posts are used as supports by growers in Binh Thuan, but living trees are used to support the dragon fruit in Long An. Yields are similar in both areas, but the quality of dragon fruit from Binh Thuan is better.

Young plants are fertilized with 10-15 kg farmyard manure plus 100g of superphosphate per plant at the time of planting. During the first two years, 300 g urea + 200 g NPK (16-16-8) should be applied to each plant every year. The fertilizer should be applied in three splits, at one month, six months, and twelve months after planting, respectively (Ke 1997).

Mature plants (at least three years old) should be given 540 g N + 720g P_2O_5 + 300 g K_2O plus 20 kg farmyard manure per plant per year for dragon fruit in the Mekong delta. The quantity is divided into four splits. The first is applied immediately after harvest, and includes 40% N + 30% of the P_2O_5 and all the manure. The second is applied two months later (30% N + 20% P_2O_5 + 15% K_2O) and the third just before flowering (10% N + 40% P_2O_5 K_2O). The fourth contains the remaining fertilizer, and is applied when the young fruit are developing (Tri *et al.* 2000). For dragon fruit growing in Binh Thuan, the rate of applied K should be higher.

Longan

Longan is mainly cultivated in the Mekong delta and southeast region. There are three main groups of cultivars: Tieu, Xuong and Long. The Tieu group is the most common, the fruit being eaten both fresh and dried. The Xuong group has the highest quality, but is slow-growing with a low yield, so that the area under production is still small.

Young longan are usually planted at a distance of 6 x 6 m. Each young tree is given 10-15 kg farmyard manure + 100 g P_2O_5 per tree. Trees too young to bear fruit (i.e. less than three years old) should be given 100-250 g N + 50-80 g P_2O_5 + 90-180 g K_2O per tree per year. Fertilizer applications should be divided into 3-4 splits (Phong *et al.* 1997).

Mature longan trees belonging to the Tieu group growing in the Mekong delta are given 400-500 g N + 80-240 g P_2O_5 + 300-480 g K_2O per tree per year, divided into four applications. The first is applied after harvest, the second before flowering, the third at the fruit development stage, and the last with the rest of the fertilizer at one month before harvest (Phong *et al.* 1997).

Hong *et al.* (2002) suggested that spraying GA3 at a rate of 25 ppm, or the soil application of Borate (32% B_2O_5) at a rate of 50-100 g/tree, helped to increase the fruit set and yield of Tieu longan.

Citrus

Pomelo (*Citrus maxima* var. Nam Roi) is popular in the Mekong delta, while mandarin and orange are widely grown in the Mekong delta. Local varieties of citrus fruits are preferred.

Fertilizer recommendations for citrus grown in the Mekong delta need to take into account the fact that the root system of citrus trees in this area is rather shallow, because of the high water table, while soils are usually lacking in zinc, copper and manganese (Hau 1999).

The recommended fertilizer application for immature citrus orchards is 50-150 g N + 50-100 g P_2O_5 + 60 g K_2O per tree per year, according to tree age. The rate is increased gradually for mature citrus trees. When the tree is 10 years old, the recommended dose is 400-800 g N + 350-400 g P_2O_5 + 240 g K_2O per tree per year, split into four applications. The application after harvest is combined with composted manure at the rate of 10-20 kg/tree (Phong *et al.* 1996).

A survey was carried out on the fertilizer applications used by growers in mandarin orchards in the Mekong delta, based on leaf

analysis. It showed that the ratio of N:P in leaf tissue was 8:1 (Thoai 1997) compared to the standard ratio of 17:1. This shows that growers are applying too much P fertilizer, and this level should be reduced. The application of zinc is essential, because the amount of zinc found in the leaf tissue is very low (16-17 ppm).

Mango

The southern part of Vietnam is considered to be the place of origin of many mango cultivars that are grown commercially, and marketed either ripe or as immature green fruit. The Mekong delta and the southeastern region are the main zones of mango production. They supply the whole of Vietnam, and also produce fruit for export, mainly to China.

When mango trees are planted, fertilizer is generally put in the planting hole. This consists of 15-20 kg of composted manure plus 1-2 kg superphosphate for each tree. The distance between trees is often 7 x 7 to 9 x 9 m. After planting, fertilizer is applied in increasing quantities as the tree grows. For the first two years after planting, mango should be fertilized with 300-500 g of NPK 16-16-8 + 300 g urea per year, divided into two split applications before and after the monsoon season (Minh, *et al.* 1997).

In previous years, there were wide fluctuations in the yields of mango. An "on year" would be followed by an "off year", unless the trees were given enough fertilizer and irrigation water. Fertilizer is the most important factor in overcoming this problem. Popnoe (1947) suggested that a reduction in the amount of nitrogen in the tissues of the tree is the main reason for the "off year".

For mature mango trees, at least 2-5 kg NPK (16-16-8) fertilizer + 1.5-3.0 kg urea should be applied per tree per year, the amount depending on tree size. If the yield in the previous years was higher than usual, the recommended dose should be increased to provide enough to meet the needs of the tree (Minh *et al.* 1997).

Fertilizers are generally applied to mango in several splits during the year e.g. at the beginning of the rainy season, or at important stages of growth e.g. pruning, flowering and fruit set (Litz 1997). They should be supplemented by zinc, copper and manganese in slopeland areas with limestone (Trinh 1995).

Mango fruits grown in the Mekong delta are sometimes split. Calcium sulfate ($CaSO_4$), lime or calcium nitrate ($Ca(NO_3)_2$) can be applied as a foliar spray to overcome this problem (Minh *et al.* 1997).

Mangosteen

Mangosteen are considered one of the most delicious tropical fruits. They are grown in both the southeast region and the Mekong delta. At present, production only just meets local demand, and only a very small amount is available for export. There is only one mangosteen cultivar. Trees are usually grown at a spacing of 8-10 m. When a site is being selected for a new mangosteen orchard, it is important that the soil has enough organic matter and a good structure, and that enough irrigation water is available.

At planting, 20 kg of composted manure + 200 g NPK (16-16-8) is put in each planting hole. During the first few years, 500 g of NPK (15-15-15) is applied to each tree every year. In the sixth year, this is increased to 3 kg/tree/year, split into 3-4 applications.

Once the tree begins to bear fruit, the proportion $N:P_2O_5$ should vary according to the different development stages, (i.e. after harvesting, before flowering, at fruit set and during fruit development: see e.g. durian above). Tan and Chau (2000) recommend a rate of 1200 g N + 600 g P_2O_5 + 1200 g K_2O + 2 kg compost when the tree is 20 years old or more.

A foliar spray at the fruit development stage is more effective than applying fertilizer to the soil. Khoe *et al.* (2002) suggested that spraying a foliar fertilizer five times at intervals of seven days after fruit set helped to increase the fruit weight and yield of mangosteen in the Mekong delta. Hau (1999) suggested that because the root system of mangosteen trees develops slowly, more composted manure should be applied (30 kg for each mature tree), and a mulch of hay or straw applied around the base of the trunk.

Rambutan

Rambutan is grown in various parts of southern Vietnam. Enough is produced to meet domestic demand, and some is also

exported to China as fresh fruit. Only a small quantity is processed into juice, or canned.

In the Mekong delta, rambutan is grown in alluvial soil along the banks of the Mekong river and its tributaries, where the soil is well drained and rich in organic matter. In the southeast region, rambutan is grown mainly in basaltic soils where the topsoil is relatively thick. Some orchards have been established in laterite basaltic, but growers need to apply large amounts of composted manure, mulch and chemical fertilizers.

It is recommended that the potassium fertilizers applied to rambutan should be in a formulation without chloride, since chloride may cause leaf burning, especially in grey Acrisols (Hau 1999).

Rambutan trees are generally planted 6-9 m apart. The basal application for each planting hole is 30 kg composted manure + 50 kg urea + 50 kg superphosphate + 50 kg potassium sulfate (K_2SO_4). To this should be added lime with a high magnesium content (Trinh 1995).

In the period before the trees bear fruit, the recommended dose is 0.7 kg of NPK + Mg (12-12-17-2) applied to each tree during the first year, rising to 3.5 kg/tree in the fourth year. This should be divided into 3-4 splits (Chau 1997). When the tree begins to bear fruit, the amount of fertilizer is increased as the tree grows, reaching 7.0-9.5 kg/tree/year. The proportion of $N:P_2O_5:K_2O$ should be adjusted according to the developmental stage, as with the other types of fruit trees. A foliar spray of phosphate monopotassium before blooming enhances flower initiation.

Nine weeks after fruit set, a canopy spray of potassium nitrate (KNO_3) helps improve the quality of the fruit. For stable yields and tree growth, growers are recommended to apply composted livestock manure at a rate of 30 kg/ tree/year (Hau 1999).

CONCLUSION

In managing their fruit orchards, Vietnamese fruit growers should take particular note of the following issues.

- *Adjusting soil pH.* Soils which are very acid should be adjusted to a neutral level before and during cultivation by measures such as lime applications, removing acid by irrigation, and applying suitable fertilizers to increase the soil pH.
- *Improving the soil's physical qualities*. Avoid compacting the soil during cultivation, grow cover crops, and apply composted livestock manure and mulches to increase the level of soil organic matter and improve the soil structure.
- *Good management of the floral community in the orchard*. Plant cover crops, but avoid competition for nutrients and light between the green cover plants and the targeted crop. After harvest, remove branches which are dead or damaged by pests or disease, and also remove "water-shoots" to promote the growth of a good canopy.
- *Fertilizer application*. Fertilize the trees with appropriate rates and nutrient proportions, according to the soil characteristics, the kind of fruit tree, and the growth stage of the crop.
- *Management of soil moisture*. Keep soil moisture at an appropriate level when applying fertilizer (30% field capacity). Avoid applying fertilizer during periods of drought or heavy rain.
- *For the low-lying orchards in the Mekong delta*. Make channels and raised beds, so that the topsoil is thick and raised well above the groundwater level. This promotes good development of the root system, prevents flooding in heavy rain, and helps reduce the acidity of the soil.

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