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FOOD & FERTILIZER TECHNOLOGY CENTER

THE USE OF ORGANIC AND CHEMICAL FERTILIZERS IN JAPAN

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FOREWORD

The high yields of modern agriculture are heavily dependent on the use of chemical fertilizers. Since the Second World War, huge amounts of chemical fertilizer, particularly nitrogen fertilizer, have been used to double or even triple yields of food grains and other crops. It is clear that in the short term, very good results can be seen from the use of chemical fertilizers, in terms of good harvests. However, in the long term many problems may occur, particularly a deterioration in the soil's physical properties. Repeated heavy applications of chemical fertilizers alone may cause environmental damage, while organic fertilizers have many advantages which chemical fertilizers lack.

Organic fertilizers help improve soil properties, and are also a way of using organic residues which would otherwise be a potential source of pollution. This is particularly important with regard to the modern intensive livestock production of the Asian and Pacific region, in which large numbers of animals are kept on a limited land area.

This important Bulletin reviews the use of organic and chemical fertilizers in Japan, where the use of chemical fertilizers is now at saturation level and where there is keen interest in nutrient recycling and organic farming. The organic materials available for use as fertilizers in Japan are reviewed, and their potential assessed. The problems involved in making efficient use of these materials for agriculture are discussed, as are the benefits in terms of soils, crops, and the demand for organically grown produce.

The paper on which this Bulletin is based was first presented by its author at an international seminar on *"The Use of Organic Fertilizer in Crop Production"*, held in Suweon, Korea in June 1990, with the co-sponsorship of the Rural Development Agency of Korea. It is one of a series of five Extension Bulletins (EB 311-315 inclusive) being published by the Center this year on the use of organic materials as fertilizers for crop production.

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(Chinese Abstract) 摘 要

改進有機物質，特別是有機廢物的應用，目前在日本肥料工業上變成相當重要的一環。爲了要減少能量及進口製造肥料的原料的消耗，存在有機廢物內植物養分再被利用至田間變的相當重要，然而處理所需費用相當高，運輸，投運困難似乎在有機廢物利用上是一個難以解決的問題。

由於對有機肥料需求大增，結果供應失調，必須大量增加進口。農民及消費者都希望有好品質食物而許多試驗顯示有機肥料不僅能增加產量，也能改善蔬菜口味，有機物對土壤微生物影響特別是土壤細菌的影響已變成重要研究課題之一。

(Japanese Abstract) 摘 要

有機物、とくに有機性廃棄物の利用をはかることは日本の肥料工業にとってきわめて重要なことである。肥料を製造するために必要なエネルギーおよび原料の使用量や輸入量を減らすために、有機性廃棄物中の植物養分を農耕地に循環させることはますます重要になっている。しかしながら、有機性廃棄物の使用には、處理、運搬、取扱いに高い費用がかかる問題がつきまとっている。さらにむずかしい問題は、廃棄物中には重金屬などの潜在的に毒性の強る物質が存在している可能性があることである。

有機質肥料に對する需要が最近高まっているためにその供給が不足しており、外國からの輸入量が急激に增加している。この需要が增加している原因の一つは、農家及び消費者が高品質な食品についての關心を深めていることにある。少なくとも野菜については、有機質肥料が收量を增加させるばかりでなく味などの品質を向上させるという明確な證據が得られている。さらに有機物が土壤微生物相、とくに土壤病原菌に對して及ぼす影響の解明が、現在の日本の研究において重要な課題となっている。

(Korean Abstract) 초 록

유기물 특히 유기성 폐기물의 고도이용은 현재 일본에서 비료산업의 중요한 부분이 되고 있다 에너지소모와 비료제조에 필요한 수입자재의 절감을 위해서 농토에 유기성 폐기물 형태로 식물영양분을 재순환시켜 주는 것이 더욱 더 중요하다. 그러나 이들의 처리, 수송 및 취급에 많은 비용이 든다는 점이 유기성 폐기물의 사용에 있어서 근본적인 문제로 보인다. 또 다른 어려운 문제는 유기성 폐기물속에 중금속을 포함한 잠재력을 지닌 독성물질들의 존재이다.

유기질 비료의 요구가 직접적이어서 공급의 부족을 초래하여 일본에서 현재 많은 양을 수입해야 할 처지에 있다. 이와같은 요구의 증가는 좋은 품질의 식품을 얻기 위해서 농민들과 소비자들간에 깊은 관심을 부분적으로 불러 일으켰다. 즉 유기질비료는 수량을 증가시킬 뿐 아니라 채소의 맛도 향상시킨다는 뚜렷한 증거가 있다. 토양미생물 특히 토양병원균에 대한 유기물 시용의 효과가 현재 연구의 중요한 과제가 되고 있다.

THE USE OF ORGANIC AND CHEMICAL FERTILIZERS IN JAPAN

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ABSTRACT

The improved use of organic matter, particularly of organic wastes, has now become an important part of the fertilizer industry in Japan. In order to reduce the consumption of energy and imported materials needed to manufacture fertilizer, the recycling of plant nutrients in the form of organic wastes onto farmland has become more and more important. However, the high cost of treatment, transportation, and handling seems to be an inherent problem in the use of organic wastes. Another difficult problem is the presence of potentially toxic substances, including heavy metals, in waste materials.

The demand for organic fertilizers has become active, and the resulting shortage of supplies has led to a recent increase in the quantity imported into Japan. This increased demand has been partly brought about by the deepening concern of both farmers and consumers to have better quality food; there are strong indications that organic fertilizers not only increase yields, but also improve the taste of vegetables. The effect of organic matter on soil microflora, and particularly on soilborne pathogens, has now become an important topic of research.

INTRODUCTION

A surplus of farm produce has caused a fall in prices and a reduced consumption of fertilizers in most developed countries. The situation in Japan is no exception. The demand for Japan to open its domestic market to dairy and beef products and other agricultural imports has become a major problem, and the lowering of production costs of domestic products so that they can compete with imported ones, while maintaining their quality, is now the major target of Japan's agriculture. Farmers are now urgently demanding a reduction in the costs of fertilizer, pesticides and farm implements.

The fertilizer industry, which once achieved large exports to the world market, has lost its competitiveness since the oil crises of 1973 and 1979. Japan is now importing sizable amounts of fertilizer from many countries, including the Republic of Korea and the Republic of China. To compete with increasing imports, Japan is making every effort to lower the production costs of fertilizer. The full utilization of organic wastes from farming, food processing, brewing, and other industries, and also from sewage and town refuse, is now widely practiced. The utilization of wastes as fertilizers has already been discussed at a previous FFTC symposium, and our case studies reported (Yamazoe and Koshino 1982). Problems arising from large-scale imports of feeds and the emission of livestock manure have been discussed at another FFTC symposium (Koshino 1988).

More recently, interest in the use of organic fertilizers has been related to the quality of farm produce. Competition in the market is so keen that farmers, distributors, and retailers want their produce to be distinguishable from that of others: quality has become the key to success in marketing. Better taste, flavor, and color are frequently more important than the price, while consumers are also greatly concerned about the safety and authenticity of farm produce. The use of farm chemicals has often been criticized from the point of view of safety, while the heavy application of chemical fertilizers has frequently

been opposed as leading to both deterioration in the quality of produce and also to environmental pollution. Not all such criticism of chemical fertilizers is based on facts – it is very frequently groundless – however, it is nonetheless widespread and persistent.

The use of organic fertilizers has shown a marked increase in Japan recently, and the shortage of domestic supplies and higher prices have resulted in a rapid increase in the importation of organic fertilizers from overseas. It seems doubtful, however, whether such a dependence on imported organic fertilizers is normal. We can all understand the principle of organic farming, as long as it is based on the recycling of nutrients, and production costs are reasonably low. However, organic farming cannot be justified as a major food-producing technology if it is too expensive, and if it is possible only because Japan's industry earns enough to buy organic materials from other countries where the local recycling of nutrients is also very important for continued food production.

SUPPLY AND DEMAND SITUATION FOR CHEMICAL FERTILIZERS IN JAPAN

The production of fertilizers has declined sharply since 1974, when it reached its peak. In 1988, production was only 1.3 million mt of plant nutrients ($N + P_2O_5 + K_2O$), only 40% of that produced in 1974 (Fig. 1). This reduced production was mainly due to a decline in exports. In the peak year of 1972, 1.7 million mt were exported, while only 0.3 million mt were exported in 1988, a mere 16% of that exported in 1972. Domestic consumption has been fairly constant over a period of 20 years, at slightly more than 2 million mt/year, on a plant nutrient basis. The rapid increase in fertilizer imports has filled the gap between demand and production. Our imports of fertilizers in 1988 were: 200,000 mt of urea; 105,000 mt of fused magnesium phosphate; 149,000 mt of N-P-K mixed fertilizers; and 506,000 mt of ammonium phosphate.

The domestic demand for nitrogen,

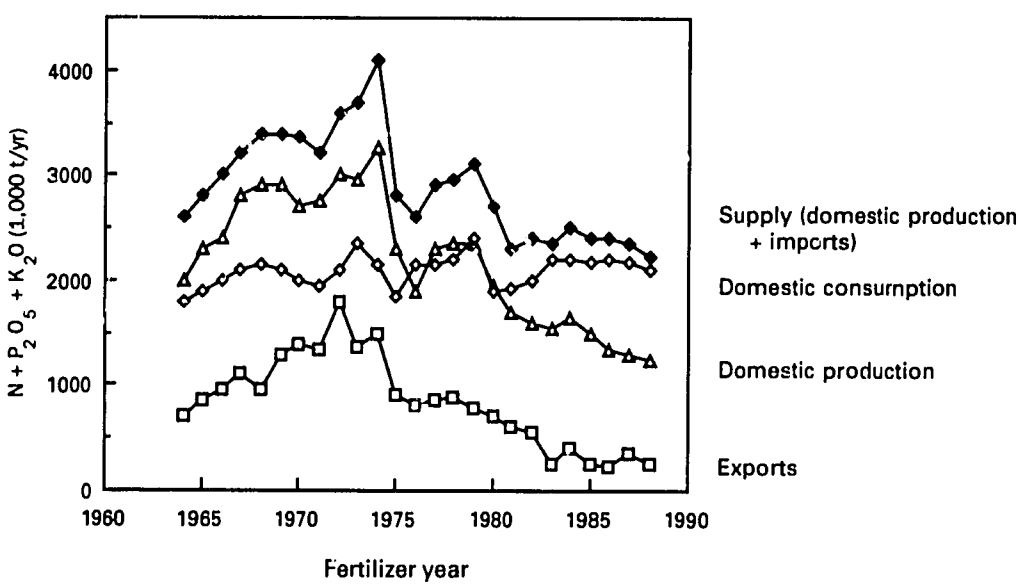

Fig. 1. Demand for, and supply and export of, fertilizers in Japan (1964-1988 fertilizer year). Survey by MAFF and MITI
(Statistics exclude those fertilizers used for industrial and feed purposes)

phosphorus, and potassium in chemical fertilizers has remained almost constant in recent years at around 700,000 mt of N, 750,000 mt of P_2O_5, and 600,000 mt of K_2O (Fig. 2). The demand forecast for fertilizer, however, shows a slight decrease over the next decade.

Japan's Ministry of Agriculture, Forestry

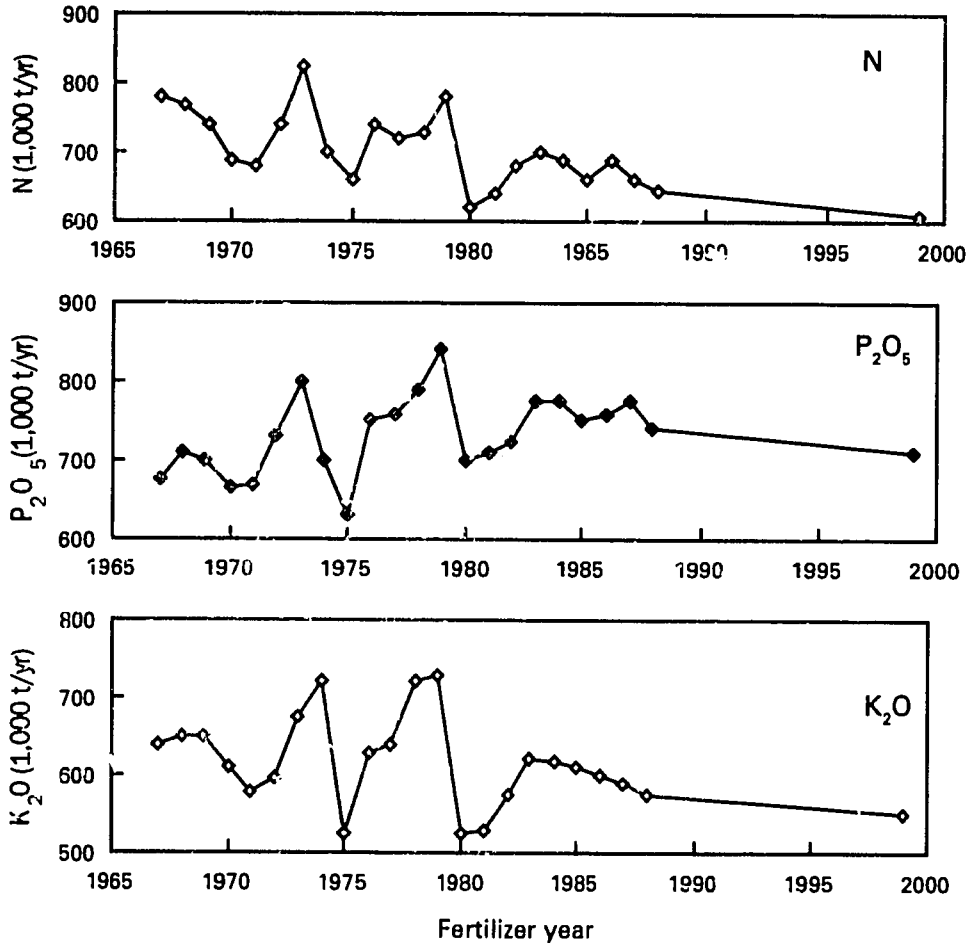

Fig. 2. Domestic demand in Japan for N, P_2O_5, and K_2O, and projected demand in the year 1999

Source: Division of Fertilizers and Machinery, MAFF, 1990

and Fisheries has recently published its analysis of the outlook for farm production and demand in the year 2000. From an estimate of cropping area and production levels at the turn of the century, the Division of Fertilizers and Machinery calculated the projected demand for fertilizers as 1,820-1,880,000 mt (Table 1 and Fig. 2). Trends in fertilizer consumption and changes in farming technology were taken into account, particularly the increase in the demand for organic fertilizers.

Table 1. Projected domestic demand for chemical fertilizers in Japan, 1999 fertilizer year

(1,000 ton)

	N	P_2O_5	K_2O	Total
Projected demand in 1999	600-620	680-700	540-560	1,820-1,880
Actual demand in 1988	640	726	577	1,944
Ratio, 1999/1989	93.8-96.9	93.7-96.4	93.6-97.1	93.6-96.7

Source: MAFF 1990

SUPPLY AND DEMAND SITUATION FOR ORGANIC FERTILIZERS IN JAPAN

The supply of organic fertilizers is shown in Table 2. These statistics are available only for commercially distributed fertilizers, and do not include self-supplied organic fertilizers such as unprocessed animal manure, crop residues, litter, and so forth. The sources of organic fertilizers in 1988 were as follows: animal origin, 424,000 mt; vegetable origin, 716,000 mt; and miscellaneous origin, more than 3 million mt. Increases in the supply of organic fertilizers over the past ten years have been remarkable, as shown in Fig. 3. Supplies of organic fertilizers of animal and vegetable origin are definitely increasing, but the most marked increase has been seen in organic fertilizers of miscellaneous origin, such as bark compost, dried (activated) sludge, etc. The use of sewage sludge also increased to 509,000 mt in 1988, mostly composted or dried sludge.

Although the *absolute* increase in organic fertilizers has been remarkable, their *relative* importance compared to chemical fertilizers has not been very high as a nutrient source in recent decades. As can be seen in Table 3, organic fertilizers supplied 74% of nitrogen in 1912, but supplied only around 5% over the last 30 years (Hayase 1989). However, if we take the recent increase in the use of organic fertilizers into consideration, we can now expect the organic nitrogen supply to rise to more than 10% of total nitrogen in the year 2000.

Table 2. Supply of organic fertilizers in Japan (1972-88 calendar year)[a]

Type of fertilizer	Supply of organic fertilizers (1,000 mt)					Share in 1988	Increase 1988/
	1972	1975	1980	1985	1988	(%)	1972
Fertilizers of animal origin	268	161	265	281	424	9.9	1.58
Fish scrap	136	58	65	55	109	2.5	0.80
Steamed bone meal	51	45	77	92	132	3.1	2.59
Fertilizers of vegetable origin	396	336	508	620	716	16.7	1.81
Soybean cake	12	6	33	8	10	0.2	0.83
Rapeseed cake	255	288	396	447	447	10.4	1.75
Miscellaneous	313	478	1,369	2,136	3,142	73.4	10.0
Bark and other compost[b]	103	229	654	1,386	1,923	44.9	18.7
Dried (activated) sludge	1	15	28	23	29	0.7	29.0
Animal and poultry manure (processed)	147	138	190	280	416	9.7	2.83
Sludge fertilizers	20	43	207	400	509	11.9	25.4
Total organic fertilizers	977	975	2,142	3,036	4,281	100.0	4.38

[a] MAFF. Fertilizers supplied by the user, such as garden compost, are not included

[b] Mostly bark compost

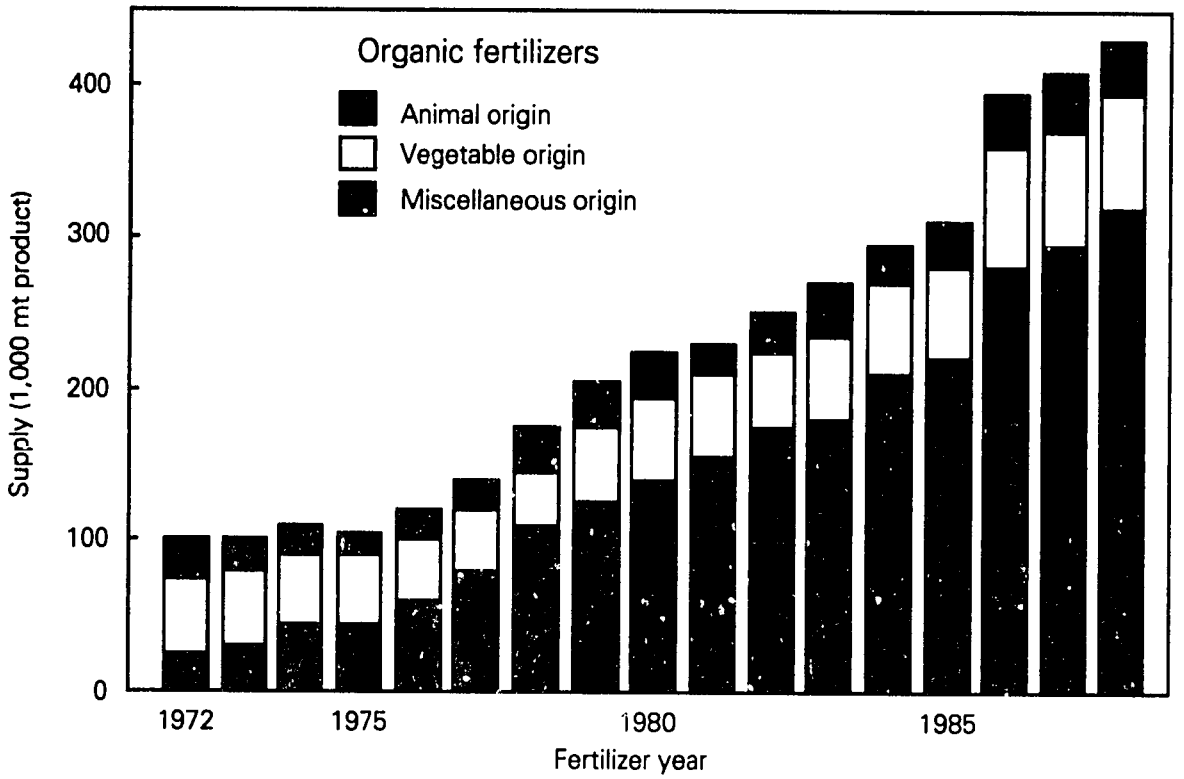

Fig. 3. Supply of organic fertilizers of different origin
Source: Division of Fertilizers and Machinery, MAFF, 1990

Table 3. Consumption of nitrogen fertilizers of inorganic and organic origin in Japan

Year	Consumption of N (1,000 mt)			Ratio of organic N (%)
	Inorganic	Organic	Total	
1912	22	62	84	73.7
1921	54	97	152	63.1
1930	144	106	250	42.5
1940	311	68	378	17.9
1949	363	23	386	6.0
1960	654	38	693	5.5
1970	642	37	688	5.3
1980	614	33	647	5.1
1985	680	35	714	4.9
1986	687	44	731	6.0

Source: Hayase 1989

To meet this rapid increase in demand, the importation of organic fertilizers is increasing. As seen in Table 4, imports of flesh bone meal, steamed bone meal and rapeseed cake have increased as much as 2.5 times over the past five years. At present, imported products occupy 20% of the total market for these three typical organic fertilizers. This table, however, shows the import of only fertilizer-grade materials. If we count the import of rapeseed from Canada and China, the share of the imported materials is almost 100% for rapeseed cake. Table 5 shows the major countries from which organic fertilizers were exported to Japan in 1987.

Table 4, Import of organic fertilizers into Japan

Type of fertilizer	Calendar year				
	1982	1983	1984	1985	1986
	Import (1,000 mt)				
Flesh and bone meal	3	5	4	10	9
Steamed bone meal	56	74	72	69	101
Rapeseed cake	17	49	41	54	118
Total	**106**	**165**	**147**	**157**	**263**
	% of import to the supply of each fertilizer				
Flesh and bone meal	15.9	23.6	13.3	30.1	18.3
Steamed bone meal	67.0	75.7	74.3	76.9	80.5
Rapeseed cake	4.9	12.9	10.3	12.2	20.9
Total	**14.3**	**19.7**	**16.7**	**16.6**	**19.9**

Source: Hayase 1989

Table 5. Imports of major organic fertilizers in 1987

Type of fertilizer	Imported from	Import (mt)
Flesh and bone meal	Argentina	5,421
	Others	690
	Subtotal	6,111
Steamed hoof and bone meal (ground)	Mainland China	3,018
	Others	1,966
	Subtotal	4,984
Raw bone meal	Mainland China	6,612
	Others	1,054
	Subtotal	7,666
Steamed bone meal	Mainland China	92,378
	Thailand	15,971
	Others	1,269
	Subtotal	109,618
Steamed leather (ground)	Korea	3,445
	Others	3,670
	Subtotal	7,115
Rapeseed cake	Mainland China	53,264
	Canada	1,526
	Subtotal	54,790
Total		**198,879**

Source: Hayase 1989

I do not believe that we either can, or should, increase the import of organic fertilizers into Japan to the extent our farmers want us to, since such organic fertilizers are also important in the countries where they are produced. Our domestic organic resources, however, are rather limited. Most organic materials such as the meal or cake from fish, flesh, bone, oily seeds, etc., are also highly valued as livestock feeds. Organic materials used as fertilizer are mainly restricted to those which are too poor in quality for feed, or those which are toxic or unsafe to animals. The potential organic resources which are cheap, not competitive with feeds, and produced in large quantities, are rather limited. Hayase (1989) has listed those organic materials which can probably be used for farming in Japan (Table 6). The largest resource is animal manure, nearly 100 million mt of which is produced annually, and of which more than 60 million mt can be used on farmland. The crop residues come next, with 31 million mt annually, of which 24 million mt can be applied to farmland. The total output of domestic refuse and sewage sludge is also large, but its use on farmland is rather limited. Public acceptance of the use of such city wastes as fertilizer has so far been very low, because they may contain heavy metals and other toxic or hazardous substances. A distaste for the use of 'dirty' substances to grow food is another problem in using these wastes.

Table 6. Potential organic material for organic fertilizers in Japan

(million mt material/yr)

Organic material	Total output	Applicable to farmland
Crop residues	30.6	24.0
Animal manure	98.2	63.0
Domestic refuse	41.1	0.08
Sewage sludge	2.3	0.35

Source: Hayase 1989

ORGANIC FARMING AND ORGANIC FERTILIZERS

The increasing demand for organic fertilizers is the result, partly of farmers' recognition of the importance of organic matter in farming, but even more of an increasing interest among farmers and consumers in organic farming. Organic farming has a long history, but has been known, or practiced, only by farmers or home gardeners in limited numbers until very recently. In the first edition of the Fertilizer Terms Dictionary (1969, in Japanese), the term "organic farming" was not included, since no editors knew of it. When we revised the edition and added the term "organic gardening" in 1978, I wrote a paragraph about it, but apparently not many were interested in it at that time. The situation was much the same in the United States and other developed countries. However, in the late 1970s, particularly after the oil crisis, people became much more concerned about shortages of energy and resources, and about food safety and the environment. Conventional chemical-intensive agriculture came under fire, and since then organic farming has been widely supported as an alternative technology.

The definition of organic farming, however, differs from person to person. For some people, it means farming which completely avoids the use of any synthetic chemicals, including pesticides and chemical fertilizers. For others, it means only farming in which organic fertilizers are used, frequently together with chemical fertilizers, though it is claimed that the amount of chemical fertilizer used is less than in conventional farming. In a report on organic farming by the U.S. Department of Agriculture (1980), organic farming is defined as follows:

> Organic farming is a production system which avoids or largely excludes the use of synthetically compounded fertilizers, pesticides, growth regulators, and livestock feed additives. To the maximum extent feasible, organic farming systems rely upon crop rotations, crop residues, animal manures, legumes, green manures, off-farm organic wastes, mechanical cultivation, mineral-bearing rocks,

and aspects of biological pest control to maintain soil productivity and tilth, to supply plant nutrients, and to control insects, weeds, and other pests.

The concerns most often expressed in relation to chemical-intensive agriculture are summarized as follows in the same USDA report.

- Sharply increasing costs and uncertain availability of energy and chemical fertilizer, and our heavy reliance on these inputs.
- Steady decline in soil productivity and tilth from excessive soil erosion and loss of soil organic matter.
- Degradation of the environment from erosion and sedimentation, and from pollution of natural waters by agricultural chemicals.
- Hazards to human and animal health and to food safety from heavy applications of pesticides.
- Demise of the family farm and localized marketing systems.

I do not believe that all these adverse effects are brought about by chemical fertilizers when they are used properly, nor can we solve these problems simply by changing to organic fertilizers. However, the principles of organic farming, which relies on the recycling of nutrients and not on the ravishment of resources, should be carefully learned from a scientific standpoint.

Despite the fact that organic fertilizers in themselves cannot be the solution to the concerns mentioned above, farmers have high expectations of organic fertilizers. The Research Union for New Organic Fertilizers, details of which will be discussed later, circulated a questionnaire when it began its activities. To the question about what kind of organic fertilizers or organic amendments farmers wanted, the most common reply was that farmers wanted organic fertilizers which could suppress soilborne pathogens (Table 7). Also favored were those with good handling properties which were easy to apply, and which released nutrients at a steady rate. Organic fertilizers which supply plant growth regulators or improve crop quality are also needed by about 10% of farmers. There is now a high incidence of soilborne diseases in vegetable fields under continuous cultivation, and vegetable growers have higher hopes than other farmers that organic fertilizers can suppress soilborne pathogens. Vegetable growers are already supplying more organic fertilizers than most other farmers, but they do not seem to be satisfied with the handling properties of these at present, since 25% of them want organic fertilizers with improved handling properties. The bulkiness and irregular shape of organic matter is likely to prevent such fertilizers from flowing freely and make mechanical application more difficult. However, a higher content of carbonaceous materials, and hence a lower content of NPK, means that organic matter is inherently more bulky. Granulation of fertilizer, a technique commonly adopted to improve its free-flowing property, is usually difficult for materials with a high organic matter content. Improving the handling properties of organic fertilizers is therefore a rather difficult task, if not an impossible one. Even more difficult is the development of organic fertilizers or amendments which can suppress soilborne pathogens.

Because organic fertilizers are in short supply and are believed to give many benefits, they are usually sold at a higher price than chemical fertilizers, if they are compared on a plant nutrient basis. According to the survey conducted by MAFF (see Table 8), the average farmer paid about US$1,080 for fertilizers in 1985, nearly 50% of which was for high-analysis mixed fertilizers (compound fertilizers). The payment for low-analysis mixed fertilizers in powder form, which are usually admixed with organic materials, was *c.* US$107 annually, or about 10% of the total cost of fertilizers. Payment for rapeseed cake came to 1.5% of this sum. Payment for miscellaneous fertilizers has increased sharply in recent years. Most of these were various kinds of organic fertilizers and amendments.

EFFECT OF ORGANIC FERTILIZERS AND AMENDMENTS ON PLANT GROWTH

Organic fertilizers and amendments have been studied for many years by both agronomists and farmers, to assess their efficiency in crop production and their effect on soil physical properties, soil microflora and microfauna, food quality, etc. Asou (1974) has summarized the beneficial effect from organic fertilizers, as shown in Table 9.

Table 7. Farmers' felt needs with regard to organic fertilizers (from the % of farmers who answered to the questionnaire)

Questionnaire	% of farmers					
	Rice	Fruit	Vegetables	Flowers	Livestock	Total
	Producers					
Organic fertilizers should:						
have good-quality organic materials	3.0	13.6	16.3	6.3	2.7	8.3
release nutrients at a controlled rate	15.2	15.5	17.5	4.2	21.6	17.4
have good handling properties at application	17.0	19.4	25.0	16.8	27.0	20.8
have the ability to suppress soilborne pathogens	19.5	19.4	25.0	16.8	27.0	20.8
supply plant growth regulators or improve crop quality	17.0	15.5	5.0	0	5.4	11.6
Compost and manure should:						
mature in a shorter period	10.4	6.8	7.5	8.4	5.4	8.3
have a less disagreeable odor during composting	6.1	4.9	7.5	8.4	10.8	6.7
No. of farmers who answered	164	103	80	48	37	432

Source: Research Union for New Organic Fertilizers 1988

Table 8. Fertilizers purchased and their cost on an average farm in Japan

Type of fertilizer[a]	Purchased (kg)				Payment (US$)		(%) in
	1972	1975	1980	1985	1980	1985	1985
Ammonium sulfate	50.9	49.1	45.1	67.3	11.1	17.2	1.6
Urea	33.1	34.3	24.5	25.3	12.4	13.2	1.2
Superphosphate	41.0	28.5	30.9	45.1	9.0	14.2	1.3
Fused phosphate	83.5	86.8	105.9	87.8	41.1	37.6	3.9
Potassium chloride	17.0	20.3	15.4	16.1	5.4	6.2	0.6
Potassium sulfate	7.9	8.3	6.5	9.3	3.0	4.9	0.5
Mixed (high-analysis)	710.8	801.6	835.2	879.9	481.4	537.1	49.7
Mixed (low-analysis)	241.6	185.1	262.3	275.3	125.6	139.4	12.8
Rapeseed cake	19.0	22.3	29.4	47.7	10.9	16.5	1.5
Lime and slag	299.3	333.1	380.7	322.9	49.5	48.1	4.5
Miscellaneous[b]					-	199.4	18.4
Total					788.5	1,081.7	100.0

[a] Does not include all fertilizers, and the sums of the figures are not the same as the totals in the Table.

[b] Includes magnesium, manganese, and boron fertilizers, soybean cake, cottonseed cake, rice bran and other seed cakes, fish scrap, animal manure, and various composts

Source: Ministry of Agriculture, Forestry and Fisheries, Japan 1990

Table 9. Beneficial effects of organic fertilizers

Direct effect on plant growth:
1. Plant foods (N, P, K, etc.) from organic fertilizers
2. Organic compounds which affect plant growth or physiological activities in plants
3. Chelate-forming compounds which stimulate micronutrient uptake
4. Others
Indirect effect through improvement of plant growing medium (soil):
1. Improvement of soil physical properties
2. Improvement of soil nutrient-supplying (or retaining) capacity
3. Effect on soil microflora (or soil-borne pathogens)
4. Others

Source: Asou 1974 (partly revised)

To discuss the effect of organic fertilizers in detail is outside the scope of this present paper, and also beyond my ability. Recent studies on the application of organic matter in Japan have been summarized and published by the National Agricultural Research Center (NARC) (1985a). Treatment, distribution, and utilization systems for organic matter, with an emphasis on animal manure, have also been published by NARC (1985b). A comprehensive literature survey was published recently by the Agriculture, Forestry and Fisheries Research Council Secretariat (1989), which included chapters on the biological control of insects, pests, and weeds, on soil improvement through the use of organic matter, and on food and feed quality in relation to the use of inorganic and organic fertilizers.

EFFECT OF PLANT FOODS (N, P, K, AND OTHERS) IN ORGANIC FERTILIZERS

The beneficial effects of organic fertilizers are rather complex and diverse, as shown in Table 9. However, the most important and noticeable effects are those due to the plant nutrients contained in organic matter. Generally, the response of plants is usually most marked in relation to nitrogen application, and this is also true with organic fertilizers.

Numerous studies have been conducted on the efficiency of organic fertilizers and amendments since the beginning of this century. Recycling of nutrients from the oil and food industries has aroused much interest, and several studies have been carried out on whether the efficiency of the present products are the same as those in the past. Table 10 compares the efficiency of past and present systems. The decomposition of nitrogenous matter in fish scrap is usually fast, and nitrogen recovery is comparatively high (around 90% of the nitrogen from ammonium sulfate). The recovery of the nitrogen from tankage, steamed bone, and soybean cake comes next (in order of efficiency), while N recovery from rapeseed cake, cottonseed cake, castor bean pomace and rice bran is somewhat lower (around 60% of that in ammonium sulfate), showing that nitrogen is released slowly in these materials. This slow-release property is frequently the basis of claims that organic fertilizers are better than readily soluble nitrogen sources in avoiding salt injury or germination injury, in prolonging nitrogen supplies into the later plant growth stages, in producing products of better quality, and so forth.

Nitrogen recovery from rice straw compost was 27% that of ammonium sulfate (Table 10). However, such values vary widely according to the material used, composting methods and facilities, the degree of maturity, additives, etc.

The relative efficiency of phosphorus in different materials is shown in Table 11. It is often claimed that there is less immobilization of phosphorus in organic fertilizers compared to inorganic sources, and

Table 10. Recovery of nitrogen from different sources

Type of fertilizer	Kawashima (1929) Barley (%)	Paddy rice (%)	Av. (%)	Relative index	Sampei (1972) Paddy rice (%)	Chinese cabbage (%)	Chinese spinach (%)	Av. (%)	Relative index
Ammonium sulfate	59.4	67.0	63.2	100	73.0	76.3	19.9	84.6	100
Herring scrap	52.6	69.3	61.0	97					
Sardine scrap	52.7	70.2	56.5	89	54.8	44.8	20.4	60.0	71
Dried sardine	54.4	54.1	54.3	86					
Steamed bone meal	53.8	43.5	48.7	77	47.5	39.0	19.1	52.8	62
Soybean cake	46.9	61.5	54.2	86	50.8	46.9	20.9	59.3	70
Rapeseed cake	33.1	42.5	37.8	60	46.8	37.3	17.8	51.0	60
Cottonseed cake					52.4	33.6	23.0	54.5	64
Castor pomace					53.5	39.2	20.7	56.7	67
Rice bran	31.2	41.5	36.4	58					
Rice straw compost	20.8	12.8	16.8	27					

Source: Compiled by Okabe, 1974

Table 11. Relative efficiency of phosphorus from different sources[a]

Type of fertilizer	Paddy rice (1935) Relative increase in yield (%)	Relative rate of P recovery (%)	Barley (1935) Relative increase in yield (%)	Relative rate of P recovery (%)	Chinese cabbage (Sampei, 1972) Relative increase in yield (%)	Relative rate of P recovery (%)
Superphosphate	100	100	100	100	100	100
Steamed bone meal	76.5	70.6	80	77	92	276[b]
Raw bone meal	74.2	50.2				
Flesh and bone meal					103	292[b]
Bone ashes	32.6	33.7	20	23		
Peruvian guano	54.6	50.2				
Sardine scrap					124	215[b]
Cottonseed cake					86	111
Chicken manure					129	203[b]

[a] Compiled by Okabe, 1974
[b] Effect of nitrogen was not fully compensated

that solubilization of soil phosphates by organic acid or chelate-forming substances produced from organic matter result in increased phosphorus recovery by plants. In an experiment using Chinese cabbage, the apparent recovery of phosphorus from organic fertilizer was much higher than that from superphosphate (Table 11). Organic fertilizers, however, also contain nitrogen, and an accurate evaluation of phosphorus efficiency which excludes the effect of the nitrogen is difficult, if not impossible.

The potassium content in organic fertilizers is usually low, and not very important as a nutrient compared to nitrogen and phosphorus. However, the content in animal manure is relatively high, and when manure is applied at heavy rates there is often an accumulation of potassium in the soil. This in turn leads to magnesium deficiency in plants, and poor quality forage.

Organic fertilizers contain varied amounts of micronutrients. The level of these is usually higher in vegetable materials than in those of animal origin. The micronutrients in organic fertilizers are available and useful in sustaining plant growth, but they may not be sufficient to correct a severe deficiency. More important than the micronutrient content may be the chelate-forming substances produced in soils after the application of organic matter. These may eventually enhance the solubilization and uptake of micronutrients in soils.

ORGANIC MATTER AS A GROWTH STIMULANT

When organic fertilizers are applied, we frequently observe that plants grow better. Vegetables, in particular, are likely to respond well to organic fertilizers. The typical yield response of vegetables to successively applied organic mixed fertilizers is shown in Fig. 4.

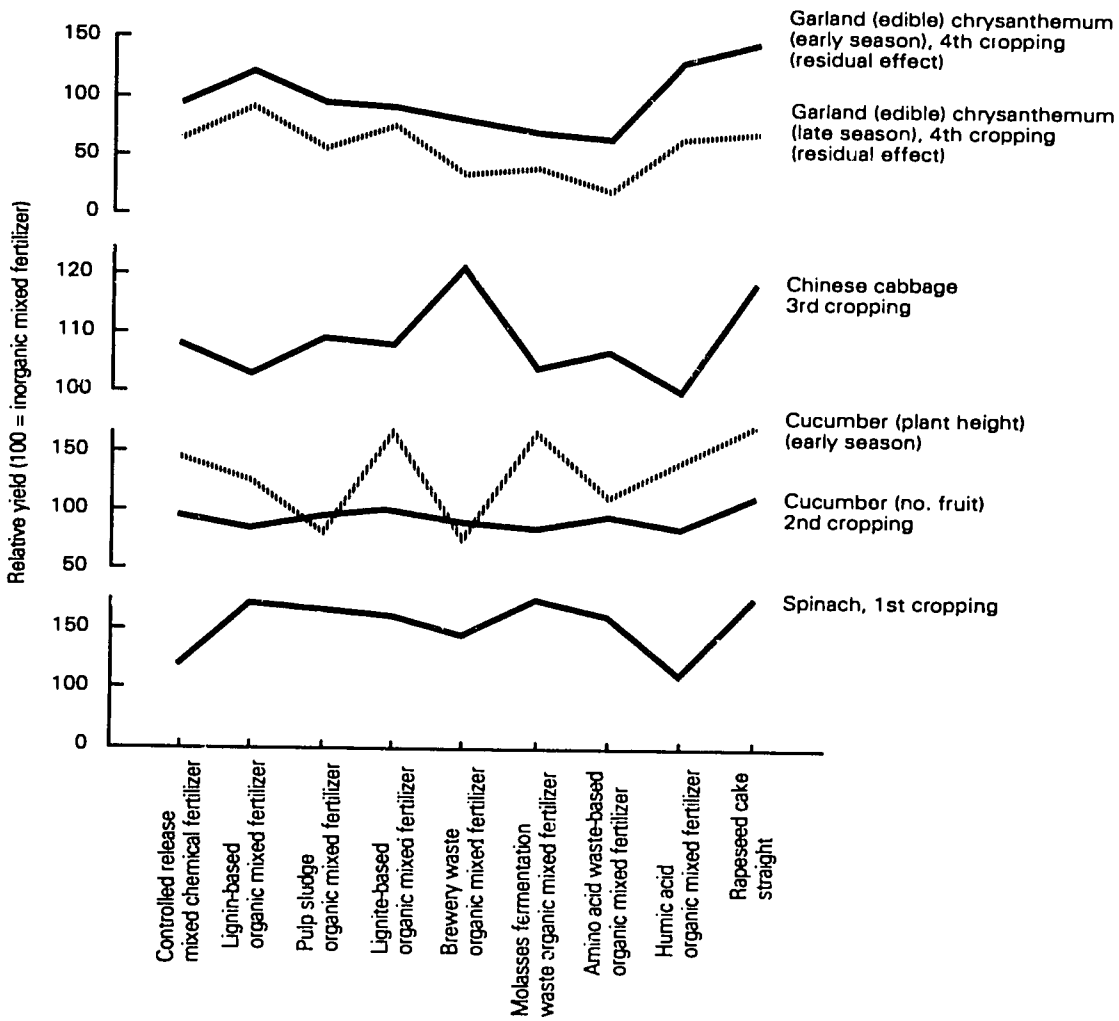

Fig. 4. Response of several consecutive crops of vegetables to various organic mixed fertilizers and inorganic mixed fertilizer

Source: Chiba Agricultural Experiment Station, Japan, 1973

The application of organic matter often results in stimulated root and root-hair elongation, improved booting, accelerated fruit-set and ripening, earlier coloring of fruits, etc., while the plant nutrient content alone cannot fully account for such effects. In cool regions, the heat produced during the decomposition of organic matter raises the soil temperature significantly during early spring, and improves plant growth. Even more interesting are the studies on growth stimulation by the amino acids, nucleic acids, polyamines, and many unknown compounds present in organic fertilizer. The results of a recent study by Matsuguchi *et al.*, are shown in Fig. 5. Naturally, not all the fractions stimulate root elongation, and some are in fact rather suppressive.

Siderophores and their possible role in suppressing soilborne pathogens are now being studied, but the contribution of organic matter in this respect is not yet fully understood.

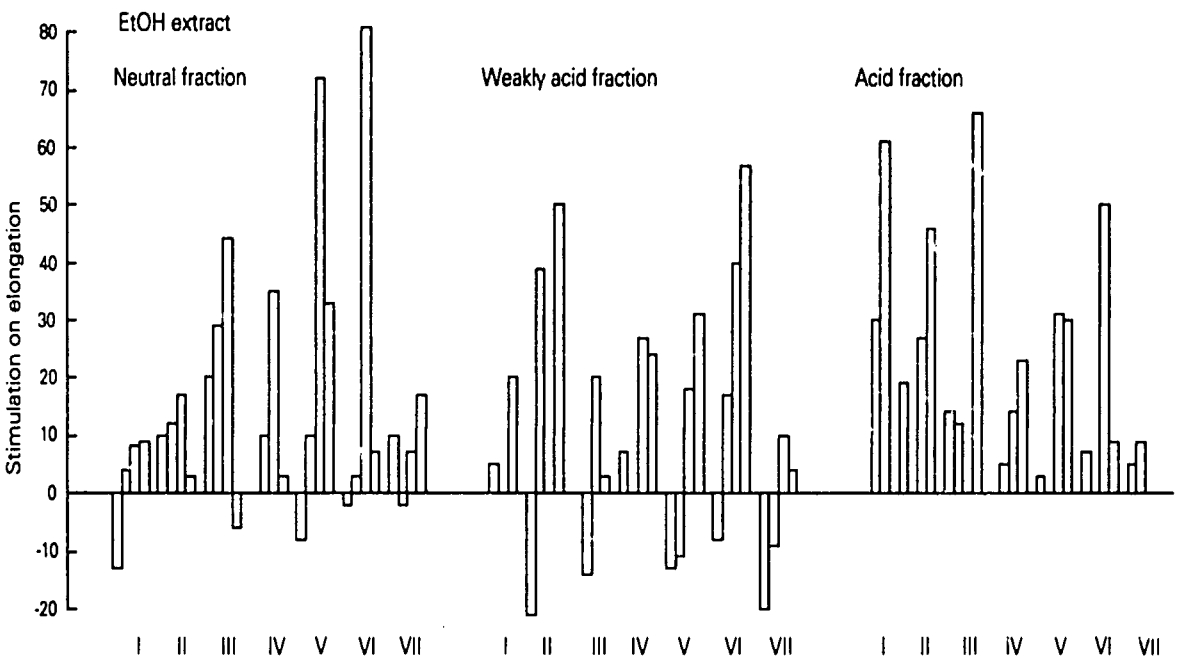

Fig. 5. Effect of various extracts from straw compost on elongation of roots of Pak-choi cabbage (*Brassica campestris* L.)
Source: Matsuguchi *et al.* 1988

ORGANIC MATTER AND SOIL MICROFLORA AND MICROFAUNA

Recently, interest in organic matter has centered on its possible role in the biological control of soilborne plant diseases and nematodes. The high hopes of farmers that organic matter will be effective has already been mentioned. Dried, composted or raw manure from different kinds of livestock, composted or raw rice straw, bark compost, seaweed, ground crab or other crustacean shells, etc., have been reported to prevent or suppress diseases of some vegetables, but the same materials have also been reported to stimulate or accelerate the spread of other diseases, or of similar diseases in different plants (Okabe 1985).

Various organic fertilizers may affect soil microorganisms differently. Recently, Noguchi (1990) has grouped fertilizers and soil amendments according to their effect on soil microorganisms, as follows:

Group A: affects microorganisms only slightly. Inorganic fertilizers such as ammonium sulfate; inorganic amendments such as

zeolite; organic materials with substances which do not decompose readily, such as sawdust.

Group B: increases the population of fungi markedly. Organic fertilizers of animal origin such as fish scrap and steamed feathers; organic fertilizers of vegetable origin such as rapeseed cake and rice bran; waste materials of vegetable origin such as rice hull and residues from coffee beans.

Group C: increases all microorganisms equally. Steamed bone meal; chicken manure.

Group D: increases the populations of bacteria and actinomycetes. Crab shell; activated sludge from ham or dairy plants; protein such as glue or gelatin; liming materials.

Group E: decreases all microorganisms. Ground sulfur.

This study suggested some organic fertilizers, if chosen correctly, could suppress the proliferation of *Fusarium* sp. and thus prevent some plant diseases; but some others may increase the pathogens in the soils and even aggravate the diseases.

A new research project is now under way at the National Institute of Agro-Environmental Sciences and related research institutions, to establish criteria for evaluating microbiological amendments. The microbiological amendments being studied in the project include those which accelerate the biodegradation of organic matter which usually takes some time to decompose, as well as those which suppress soilborne pests and insects (nematodes), and those which improve the growth of root systems in soils.

Biological pest and disease control by the use of organic fertilizers has also been a major target of the Research Union for New Organic Fertilizers.

ORGANIC FERTILIZER AND FOOD QUALITY

The Plant Protection Division of the Ministry of Agriculture, Forestry and Fisheries has recently conducted a survey on organic farming, and found the major motivation behind farmers' adoption of organic farming. The strongest motivation (23.1%, or 369 cases out of the total of 2,553 farmers surveyed), was to produce farm produce with a good flavor. The second most common reason was consumer demand for organically produced foods (17.3% or 276 farmers); this also included consumer demand for better tasting food.

There have been long arguments, which still continue, over whether organic fertilizers really do produce a better taste in food. The National Federation of Agricultural Cooperatives has conducted a series of experiments to compare paddy rice produced organically with that produced inorganically. The results showed no significant difference in functional tests (Hayase, personal communication 1989). Vegetables are more responsive, and vegetables with a better flavor are more likely to be produced with organic fertilizers (Morikuni 1989). The slow-release nitrogen contained in organic fertilizers results in a lower protein and a higher sugar content in the plants, both of which give the produce a better taste. The lower and more stable moisture tension frequently found in soils to which organic fertilizers and amendments have been applied have a favorable effect on the moisture status of plants, giving produce a higher content of sugar, ascorbic acid, β-carotene, etc. A possible mechanism through which this occurs is shown in Fig. 6 (Mori 1986).

CONCLUSION

A major target of today's agricultural research is to find how to establish sustainable farming systems, in which nutrients are recycled and used as efficiently as possible, so that losses to the environment are minimal and resources are saved for future generations to come. The use as organic fertilizers of organic matter such as waste materials from both farms and off-farm industries should be encouraged, to accelerate the recycling of nutrients. However, organic matter which also has a high value as livestock feed is likely to be used in this way, so its potential use as fertilizer is rather limited. The comparatively high price of organic fertilizers may also limit their acceptance.

Another major target of agricultural research in Japan is how to keep producing safe and authentic food, at lower cost and on a larger scale. It is widely hoped that the use of organic fertilizers and amendments will be a way of achieving this. However, it will be a very difficult task, and we must employ every innovative technology at our disposal,

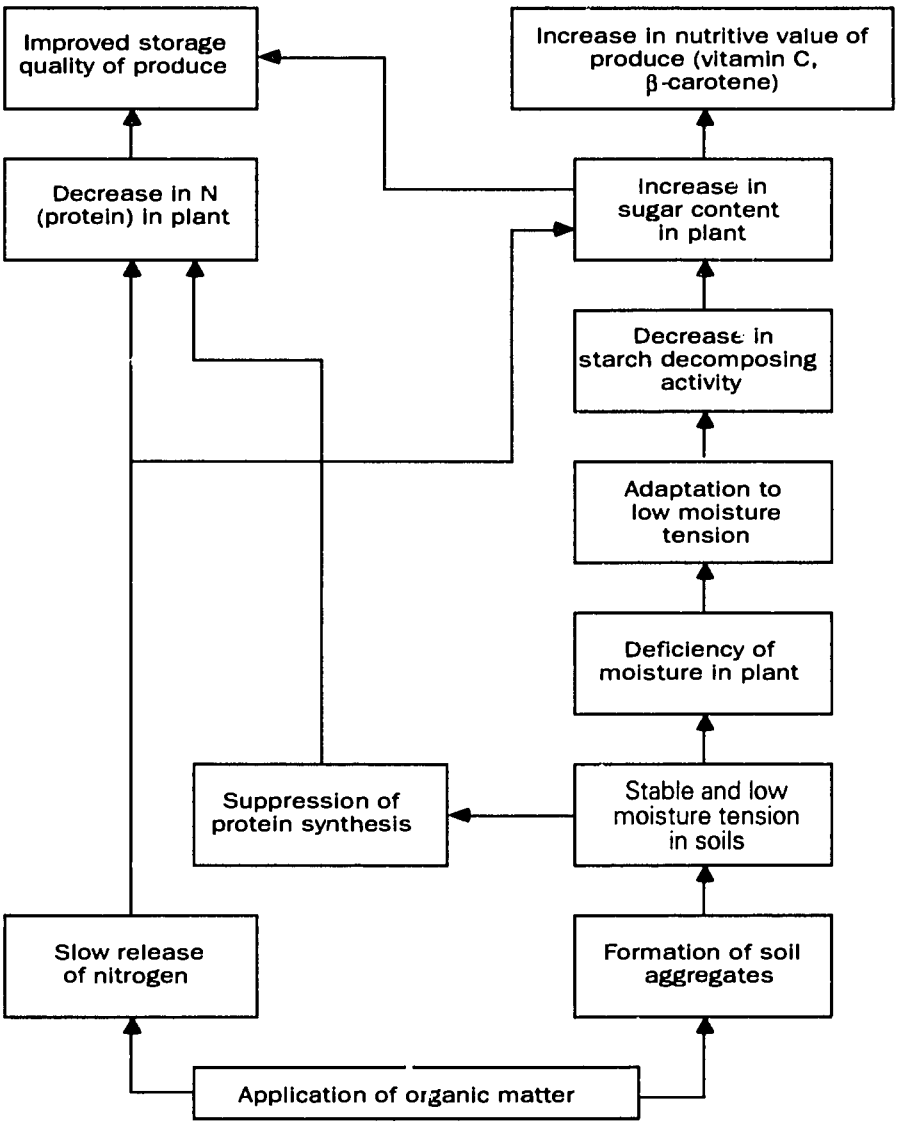

Fig. 6. Mechanism by which the application of organic matter may improve the quality of produce
Source: S. Mori 1986

including biotechnological methods of studying microbiology.

The Division of Fertilizers and Machinery of MAFF has organized and sponsored since 1987 the Research Union for New Organic Fertilizers. The objectives of the Research Union are:

- to develop new and improved processes for the production of fertilizers by the use of biological activity, and
- to develop new and improved fertilizers which have the ability to supply nutrients at a rate which matches plant growth, to suppress soilborne diseases or nematodes, or to increase the value of fertilizer by other means.

At present, more than 20 fertilizer companies have joined the Union, and are actively conducting research along these lines. Many people are now active in the field, and an interim account of their achievements was published last fall.

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