# THE CHARACTERISTICS OF HEAVY APPLICATIONS OF FERTILIZERS IN JAPANESE AGRICULTURE

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## I

The marked development which has taken place in the productivity of Japanese agriculture since the Meiji Restoration of 1868 is strikingly shown by the yields of the most representative crop—rice. In general terms, the yield in unpolished rice per hectare at the beginning of the Meiji period was approximately 1,500 kg, and before the last World War it had exceeded 3,000 kg, while after the war, around 1960, it again rose steeply, and is at present about the level of 4,000 kg. In Japan, as large an area as possible is devoted to rice cultivation, including poor land in mountainous areas and land which is inadequately supplied with water, and in areas other than these, where rice cultivation is carried on under ordinary conditions, the yields are in general over 4,500 kg per hectare. Indeed, in the main areas of rice cultivation it is not uncommon for yields to exceed 6,000 kg per hectare. In contrast, the yields per hectare in the rice-growing countries of Southeast Asia are in general under 2,000 kg, and are thus roughly at the same level of productivity as those of Japan a century ago when Japan embarked on her course as a modern state.

Many factors were of course responsible for this development of productivity in Japanese rice cultivation, but it is widely recognized that an increased investment in fertilizers was predominant over much of the process. Needless to say, the development in productivity was not due to fertilizer applications alone, but to the selection of varieties of rice suited to heavy applications of fertilizers and to the perfection of the so-called Japanese system of rice cultivation which made the use of fertilizers effective; these are facts which should not be forgotten. However, the original nature of Japanese agriculture which made these developments possible consisted of a labour-intensive form of agriculture

practised on holdings of minute scale. Thus, the average agricultural holding in Japan is one hectare in area, but if we exclude the island of Hokkaidō, where comparatively large-scale agriculture is practised, the figure for the remainder of the country is only 0.8 hectares. Further, the holdings are mainly distributed in the range between 0.5 and 1.0 hectares, and 2-3 hectares may be regarded as the upper limit of large holdings in the area outside Hokkaidō.

From the point of view of Europe and America, this Japanese system of agriculture, practised on a small scale and presupposing a heavy investment of family labour, appears to partake more of the nature of garden culture than of field culture. That is to say, from ancient times in Japan even grain crops have been cultivated not as field crops but as garden crops in the Western European sense.

However, in the nature of the case there is a limit to the raising of yields by labour-intensive methods. In general, a positive raising of yields means a raising of the fertility of the soil, and in doing this it is considered that manures produced on the holding have an overwhelming importance. However, in the traditional form of Japanese agriculture there has always been a deficiency of manures produced on the holding, and in spite of the fact that garden culture has been carried on with very careful methods of cultivation, it has been impossible to raise the yields of crops very much, and the productivity of labour has remained at a very low level. As a result, the standards of living of the peasantry have been low, and this fact has driven the peasantry to ever greater industry in the attempt to raise yields, even if only slightly, by means of increased investment of labour. This vicious cycle of labour and poverty necessarily manifested itself in a demand for commercial fertilizers produced outside the holding as a means of raising yields.

This necessity first manifested itself in the form of a demand for fish meal and oil-cakes in the period extending from before the Meiji Restoration up to the middle of the Meiji period, but because of the limited quantities produced and their high prices these fertilizers were not applied in ample quantities except to special crops grown for the market. However, from the time of the Russo-Japanese War comparatively cheap soybean cake became available for importation into Japan from Manchuria, and about the same time chemical fertilizers began to come on to the market, with the result that the increased use of fertilizers in Japanese agriculture proceeded with the help of these fertilizers. Before the Second World War Japan had produced a form

of agriculture which was in the same class as those of the most advanced fertilizer-intensive countries in the world, such as Holland and Belgium, in respect to the quantities of chemical fertilizers (especially nitrogen fertilizers) applied per hectare of cultivated land.

It is clear from the figures for the yields of rice quoted above that a considerable rise took place in the productivity of Japanese agriculture as an accompaniment to the increased applications of fertilizers, but since this rise was brought by a combination of increased fertilizer applications and increased input of labour, the productivity of labour did not advance to the same degree as the productivity of the land. Furthermore, the minute scale of the individual holding repressed the effect on agricultural incomes of the increases in yields, so that the economy of the peasantry was unable to free itself entirely from its condition of poverty. It is indeed true, however, that the poverty of the peasantry was largely due to the exaction of high rents under the feudal system of land tenure which was continued substantially unchanged after the legal abolition of feudalism at the time of the Meiji Restoration, and in this respect the Land Reform implemented after the Second World War effected a considerable improvement in the economy of the peasantry by diverting these high rents to their agricultural incomes. This increase in agricultural incomes not only encouraged investment in chemical fertilizers, but also produced the noteworthy phenomenon of a rapid and nation-wide spread of investment in garden tractors and other agricultural machinery which before the war had been in use only on a very small scale.

As a result of the mechanization of agriculture which took place after the war, the excessive labour-requirements which had weighed upon the peasantry in the past were to some extent alleviated, and the productivity of the unit of labour rose to a fair degree. However, these forms of investment cannot be said to have paid for themselves economically in every case, and the opinion has even been expressed that these are "excessive investments." This development has something in common with the motives which have led to the rapid diffusion among ordinary households of such durable consumer goods as electric washing machines, television sets, and refrigerators, a part of the rapid Euro-Americanization of life in general which has accompanied Japan's economic growth since the war. That is to say, this development may be interpreted as being the effect on the demand for garden tractors, etc., in the small peasant economy in which the holding and the family budget are not kept separate, of so-called

"demonstration effects" related to consumer goods purchased with the aid of increased incomes. In the same way as television sets have now been installed in many poor homes, garden tractors, etc., have been introduced on many small peasant holdings.

It is true, however, that at present the smallest holdings (those of 0.5 hectares and less) are not necessarily the poorest. This is because among peasants of this class the sudden increase in demand for labour in secondary and tertiary industries which has taken place since the war has caused most of the male workers in agricultural families to leave agriculture in order to seek increased incomes from non-agricultural employment. With these increased incomes agricultural machinery has been bought which has lightened the burden of agricultural work in the same way that the purchase of electric washing machines has lightened the burden of housework. Consequently, there have been many cases in which peasants have regarded such machinery as the means by which they could undertake some form of non-agricultural work, if they ignored the problem of returning the original cost of the investment.

However, I have no intention of putting forward a general negation of the significance of the development of agricultural mechanization in Japan since the war, and of stressing only the negative aspect of the matter. On the contrary, as has frequently been pointed out, the development of agricultural mechanization is of course important in any attempt to raise the productivity of labour and to divert traditional Japanese agriculture away from the exclusive pursuit of an increase in the productivity of the land, regardless of the productivity of labour. But it must be thought difficult for mechanization to be effective in terms of economics so long as agriculture is practised on minute holdings. For a rational development of mechanization, there is a necessity for the necessary preconditions for mechanization to be fulfilled. At the same time, I should like to point out that it cannot be said to be wise to devote exclusive efforts to the raising of the productivity of labour, merely as a reaction to the pursuit of increased productivity of the land which has characterized Japanese agriculture in the past.

Many people seem to think that, since the productivity of the land in Japan is high in the international scale, if only the productivity of labour could be increased not only would the peasant economy be improved but Japan would acquire a stronger position in international competition. However, at present it is only in the case of rice that the productivity of the land is strikingly high in the international

scale, and it need hardly be said that in the cases of wheat and barley (the index crops in international comparisons of agricultural productivity), as well as in the cases of such garden crops as root crops, vegetables and fruit, the yields are by no means high in comparison with those of the various countries of Europe and America. In other words, it has become impossible for us to say that levels of productivity in Japan are superior to those of the countries of Europe and America at the present time, even in the cases of garden crops in which labour-intensive garden culture can be exploited to the greatest advantage. Whereas there has been a sudden increase in the consumption of chemical fertilizers in Europe and America since the war, with a consequent rapid rise in the yields of all crops, Japan, in spite of increased investment in chemical fertilizers has been unable to obtain corresponding increases in crop yields other than rice, that is, among unirrigated crops.

It need scarcely be noted that rice, the crop which Japan produces at a high level of productivity in the international scale, is a subtropical plant grown under special conditions——those of the irrigated rice field——and since the greater part of the rice produced throughout the world is produced in the monsoon regions of Asia, Japan's high level of productivity in the international scale is maintained only in relation to China and the rice-growing countries of Southeast Asia.

Rice is the most representative crop in Japanese agriculture, being grown on approximately half of the total cultivated area, and it provides the largest single source of income for the peasantry, but the total production is not sufficient to exceed the requirements of domestic food consumption and provide a surplus for a positive export trade. Further, Japanese rice differs from the Indica varieties of rice grown in the countries of Southeast Asia, coming under the botanical classification of Japonica, and in commerce it is considered to be a special article suited to the Japanese taste. Again, it may be said to be fortunate for the Japanese peasant that in Japan government control of rice has been continued since the war, so that the crop has been set outside the sphere of international competition and its price has been maintained at high levels. However, even in the case of rice-growing carried on under these special conditions of protection, the restrictions on income imposed by the minute scale of operation in agriculture have caused the gap between the incomes of rice-growers and industrial workers to widen under the influence of the high rate of economic growth in the period since the war, and it is gradually

becoming more difficult to maintain agricultural holdings dependent on rice cultivation. Under the influence of the fierce international competition which has accompanied the freeing of trade, Japanese crops other than rice and animal products would seem to be about to show up the weaknesses of Japanese agriculture.

In response to this situation, the Japanese government passed the Basic Agricultural Law in 1961, and with the help of vast state subsidies made available under its provisions, work has begun on the promotion of economically viable units in agriculture by means of mechanization with large-scale machinery. It is expected that a number of difficulties will have to be surmounted in carrying out this programme. Even if we suppose that the productivity of labour in Japanese agriculture can approach the levels of Europe and America, we may consider it necessary to reflect on the manner in which increases in land productivity have been pursued in the past, since there are signs that land productivity, of which fertilizers have been the main support in traditional Japanese agriculture, is now declining in terms of international comparisons. The present paper is an essay on this subject.

## II

As has been stated above, the application of large amounts of fertilizers in Japanese agriculture has been brought about principally by increased investments in commercial fertilizers produced outside the holding, particularly chemical fertilizers. But it scarcely need be said that such applications of fertilizers are only one of the forms in which nutriment is supplied to the plants and do not monistically prescribe the fertility of the soil. The case is quite otherwise. It cannot be denied that the main force operating in the direction of increased soil fertility has always been greatly dependent on soil-fertility maintenance within the holding and the mechanisms employed in strengthening it. This was, of course, the case under the conditions of a natural economy, and still is so at present. It is now proposed to examine the special characteristics of Japanese agriculture in comparison with the agriculture of Western Europe, limiting the scope of discussion to manures and rotations——two aspects of management which may be considered the most important of the means employed in maintaining and strengthening the fertility of the

soil within the holding.

*1. The Question of Manures*

In general, composts and stable manures are representative of the fertilizers produced on the holding, and especially under the conditions of a subsistence economy they possess an indispensable importance as the sole source of fertilizers. In such conditions it is no exaggeration to say that the amount of these fertilizers applied prescribes the productivity of the land. In Western European agriculture the fertilizers produced on the holding are mainly derived from the dung of animals produced by an organic combination of arable husbandry and animal husbandry, and these fertilizers would appear to have passed through the following course of development in their role of supplying plant nutriment from within the holding.

First, at the stage of the three-field system which was representative of the feudal agriculture of Western Europe, the system employed is said to have been that of transferring fertilizing substances from natural grasslands to arable land. Under this system, animals were pastured on the extensive natural grasslands attached to the arable land and the grass of these pastures passed through the stomachs of these animals to produce dung which was then transported by the animals to the arable land——the system which C. S. Orwin has described as being one in which the animals performed the function of a "four-legged dung-cart." This system was in use throughout the long period of the Middle Ages. However, in this pasturing system, dependent as it was on natural grass, the greater part of the dung of the pastured animals was wasted and the supply to the arable land was insufficient, with the result that it was impossible to enhance the fertility of the soil. For this reason, a low level of productivity was rendered inevitable in the agriculture of the Middle Ages.

However, the move towards the modern system of agriculture which took place in the 16th and 17th centuries produced the so-called convertible husbandry system in which a part of the arable land was made into temporary pasture or ley by the sowing of perennial grasses, the land being returned to arable use after being grazed by animals for a certain period of years. In this system of agriculture, not only was the dung of the animals pastured on the artificial grasslands returned to the soil in its entirety, but the physical composition of the soil was improved by the root residue of perennial grasses, and in this

way a fair advance was made in land fertility.

The next advance took place with the appearance of the modern European system of crop rotation, evolved in England in the second half of the 17th century. In this system annual leguminous grasses (of which red clover was representative) and root crops (of which turnips were representative) were planted in enclosed fields in rotation with grain crops. Under this system, not only was it possible to supply highly nutritious good quality red clover grass to stall-fed animals during the summer, but it was also possible, by means of an ample supply of superior root feed having a high liquid content, to make good the deficiency in winter feed which had hitherto been a great obstacle to animal husbandry. In this way a rapid increase was brought about in the number of animals kept throughout the year and in the productivity of animal husbandry. As an accompaniment, the rich supply of dung produced by these animals was returned to the arable land, causing a great upward leap in the productivity of the crops. Further, this rotational system did away with the necessity of having large areas of permanent pasture attached to the arable land, as was inevitable under the three-field system, and of leaving arable land in a state of bare fallow for one year in every three. In this way it was made possible for the greater part of the potentially arable land to be brought under arable cultivation and for the whole of it to be cultivated in the manner above-mentioned. As a result, the sown area increased and at the same time the fertility of the soil was cyclically strengthened by the expansion of the basis for the production of feed and dung, while the expansion of the sown area of grain crops was accompanied by an upward leap in yields. It was in this manner that in Western Europe, although admittedly in varying degrees, modern commercial production developed by means of a parallel expansion of the productivities of field crops and animal husbandry, dependent on the strengthening of the self-sufficient feed-and-dung base on the individual holding which accompanied the modernization of agriculture.

The state of Japanese agriculture provides a marked contrast to this scheme of development in the agriculture of Western Europe. In Japan, too, during the stage of natural economy, it was necessary to rely exclusively on natural grasslands outside the arable land as the source of fertilizers used in maintaining the fertility of the arable land, but in Japan there was no room for the establishment of broad areas of grassland which might be organically combined with the arable

land (the arable land being limited in relation to the population of the village), and, in particular, there were in general no areas of permanent grass which could be used for pasture, apart from certain areas located in mountainous regions. Consequently it was impossible for the peasants to adopt the method of supplying dung to the arable land by means of pastured animals, but although they were insufficient in the main, grasslands were utilized as a source of fertilizers by means of human labour. Peasants collected grass with the sickle from steep slopes and waste land, as well as leaves and grass from such common forest and moorland as they possessed. A great deal of labour was required in the collection of grass in this manner, and it may be said that even when they were not employed in the cultivation of their crops, there was no slack season for the peasant except during the winter. This was an instance of that industriousness among the Japanese peasantry which was the occasion of some astonishment among Western Europeans. However, the German agricultural scientist Max Fesca, who came to Japan at the beginning of the Meiji era, pointed out that the quantity of fertilizers which could be collected by such industriousness was severely limited, and further, that the grass was in general of poor quality. The use of night soil, however, was a special characteristic of Japanese agriculture which was not found in Western Europe, but in this case, too, the fertilizer was used in large quantities only by peasants growing garden crops near the towns, and the amount available for use among the peasantry in general was limited. However, in the case of rice it was possible to maintain a certain level of productivity even under conditions of fertilizer shortage, thanks to the supply of natural fertilizing substances contained in the irrigation water fed to the rice fields. But because of the shortage of fertilizers produced on the holding for application to unirrigated crops, this latter branch of Japanese agriculture was only able to attain levels of productivity which were far below those of Western Europe.

The advent of the Meiji era produced an aggravation of this shortage of fertilizers in Japanese agriculture. This aggravation consisted in the further reduction of the area from which the peasants could freely collect grass which resulted from the conversion of common forests and moorlands to privately-owned land and the opening-up of land formerly unused for agricultural purposes. On the other hand, the collection of the land tax in money, instead of in kind, a change introduced by the Meiji Government, and the penetration of a money economy into the villages resulted in an increased demand among the

peasants for commercial forms of production which would provide a monetary income. However, the shortage of fertilizers prevented a rise in yields, and under the conditions of a commercial economy the heavy input of labour in land assumed more and more the character of "disguised unemployment" tied to the land. This condition came about because the Japanese peasantry made increases in land productivity their first consideration when undertaking commercial crops. It was therefore of necessity that there appeared an unusual demand for commercial fertilizers. The commercial fertilizers in this period were, as has been said above, home-produced fish meal and vegetable oil-cakes, but because the sources of supply were limited and the prices high there was not enough to meet the entire demand. However, after the Russo-Japanese War the importation of soybean cake from Manchuria began, and because the price was comparatively low the consumption of soybean cake increased suddenly. About the same time the demand for home-produced superphosphate of lime, calcium cyanamide, and by-product ammonium sulphate, the production of which had just commenced, was showing a gradual parallel increase, and after the first World War the importation from Germany of cheap ammonium sulphate made by the synthetic ammonia process, and later the availability of rich supplies of ammonium sulphate consequent upon the rise of the Japanese ammonium sulphate industry after about 1925, kept pace with the peasantry's strong demand for fertilizers. In this way the consumption of these fertilizers increased rapidly, and Japanese agriculture entered the first rank of fertilizer-consumers in the international field.

Thus, in Western Europe the process of development proceeded from the three-field system through the convertible husbandry system to the modern crop rotation system. This process was paralleled by an improvement in the fertility of the soil within the individual holdings which led to an increase in the productivity of agriculture and then the expansion into commercial production. When chemical fertilizers appeared they were used in a supplementary or secondary function of supplying plant nutriments within the framework of these processes. However, in Japanese agriculture the function of maintaining the fertility of the soil within the individual holding underwent a process of degeneration. This fact revealed itself in a huge consumption of commercial fertilizers, especially chemical fertilizers, as the sole means of supplementing and strengthening soil fertility.

*2. The Question of Rotations*

The question of the rotation of crops is of importance in considering the utilization of plant nutrients by the crops, as distinct from the supply of nutrients by means of fertilizers produced on the holding, or by chemical fertilizers.

There are differences among plants in regard to both the quantities and the types of fertilizers required, but it is generally considered that in general grain crops (*Halmfrüchte*) deplete the fertility of the soil, while green crops (*Blattfrüchte*) such as the leguminous grasses (the clovers, etc.) and root crops, etc., promote the fertility of the soil. The principle of systematic crop rotation consists of the use of a rational combination of fertility-depleting grain crops (H) and fertility-promoting green crops (B) in the order H–B–H–B.

At the stage of the feudal three-field system in Western Europe the arable land was used exclusively for grain crops, and the usual order of rotation was winter-sown grain crops (wheat or rye)——spring-sown grain crops (barley or oats)——fallow. This system, containing as it does a succession of two grain crops H–H, tends to delete the soil, but, as has been described above, Western Europen agriculture had a mechanism for supplementing the deficiency in the form of the dung of animals transported from the natural grasslands to the arable land. The year of fallow observed after the two successive years of grain crops is frequently regarded as having had the function of allowing the fertility of the soil to be restored, but the main aim of this practice lay in the ploughing of the bare land three or four times, that is to say, in removing weeds from the land by means of tillage during the fallow period. In particular, the summer fallowing——the ploughing of fallow land in summer between July and August——was considered indispensable for the removal of pestilent root-weeds. Further, since the dung brought from the natural grasslands naturally contained the seeds of weeds in large quantities, and since there was a danger that if this dung were applied directly to the land used for grain crops the weeds would sprout in large numbers at the same time as the grain, and, growing with wild vigour would overpower the grain and reduce yields, the dung was applied beforehand during the fallow period and the seeds of weeds contained in it allowed to sprout, and after these had been removed by several ploughings and harrowings the winter-sown grain crop (wheat) was sown. That is to say, the fallow land also had an important significance as fields which could be fertilized in safety by means of dung from which the danger of

producing weeds had been removed. Again, at this period crops were sown broadcast, and it was necessary to sow thickly——two bushels of wheat per acre was the standard sowing rate in the Middle Ages—— in order to suppress the growth of annual weeds among the sown crops. This was because, at this period, ploughing and harrowing were carried out with animal-power (usually by teams of 4-6 oxen or horses), but there was no means other than hand labour for sowing the crops and for hoeing and weeding them in the course of their development, and it was thus altogether impossible to carry out these processes over the large areas used for grain crops. Consequently, such "hoed crops" as the root crops, could not be grown as field crops at this period, but were grown with the aid of hand-hoeing in kitchen-gardens.

At the stage of the grass-arable system which succeeded the three-field system, not only was the fertility of the soil increased by a regular interchange between arable and artificial pasture, but the mechanism of getting rid of weeds by the mutual suppression of weeds of the arable land and those of the pasture land was evolved. The resultant changes which came about in the order of planting of crops tended to promote continuous arable utilization, the land being used for grain crops for about 4–5 years in succession.

It was the invention of the animal-drawn drill and horse-hoe which brought about a great change in crop rotations in the period which followed the three-field and convertible husbandry systems.

In England the idea of the drill was conceived by Gabriel Plattes, John Wolridge and others in the 17th century but, as is well known, it was the publication of Jethro Tull's *Horse-Hoeing Husbandry* (1731) which was instrumental in bringing the device into practical use. The appearance of the drill and the horse-hoe in England permitted root crops, hitherto cultivated as garden crops, to be cultivated as field crops, and, with the introduction of high-quality and high-productivity annual pasture grasses (red clover) into the fields, the modern system of rotation of crops was established. The Norfolk four-course rotation, which is considered to be typical of this system, consisted of wheat—turnips—barley—red clover, and its structure may be represented, with the help of the notation mentioned above, by the formula H–B–H–B. In this system, crops which deplete soil fertility and crops which promote soil fertility are combined together, and it is now widely recognized how superior it is from the point of view of raising the fertility of the land. Under this system, as we have noted above, large quantities of high-quality dung produced by animals fed with

ample supplies of red clover, root crops, etc., are returned to the arable land. Further, it has now been proved by a wealth of experience that the combination of dunging with rotations is far more efficient in promoting soil fertility than either of the two in isolation. Not only is the dung safe, since it contains practically no weed-producing seeds, but the growth of weeds during the development of the crops is also prevented, since complete freedom from weeds can be assured by horse-hoeing between the rows of the drilled crops, and by means of row culture the production of grain is increased above the level attained with the former broadcast method of sowing because the tillering of the plants is encouraged, so that it becomes possible to produce much higher yields with sowing rates lower than those employed with the broadcast method of sowing.

Great changes in the order of sowing of crops such as those which took place in Western Europe did not occur in Japan. This was because from the earliest times in Japan grain crops and all other crops were, as a general rule, grown in rows and hoed by hand labour. Thus all crops cultivated were "hoed crops" in the Western European sense, and the fundamental Western European distinction between "field crops" and "garden crops" did not exist. Further, rice was cultivated continuously from year to year in irrigated fields by means of a method of transplanting which required even more labour than ordinary row cultivation. In upland field, too, such grain crops as wheat, barley, upland rice, millet, etc., are grown every year in rows, but since Japan's climate makes it possible to grow two such crops in one year, it is usual for wheat and barley to be grown during the winter, and for the land to be used for some other crop during the summer. That is to say, in Japan successive grain crop cultivation without fallowing (H–H) has been dominant from the earliest times. It is true, however, that leguminous plants such as soybeans, together with cotton, hemp, rape, and vegetables, were grown in unirrigated land, and in this sense a succession of crops similar to the B–H–B–H rotation is found in Japan, but such successions of crops did not have the significance of being a definite system as in Western Europe. The minute holding of the Japanese peasant was made up of a number of small plots of cultivated land distributed over a considerable area, and crops were grown in each of these small fields in isolation from one another, so that it was difficult to set up an orderly system governing the succession of crops on the holding as a whole. Consequently, the distinction in land utilization between arable land and

garden plots was not clearly defined, necessary crops of various kinds being sown or planted in scattered parcels of land as convenience dictated. Although grain crops and green crops may have followed one another in certain of these small plots of land, this did not mean that over the holding as a whole the crops were organized in a systematic order of succession designed to promote the fertility of the soil, as distinct from successive grain crop cultivation. The tendency was rather for intensive forms of land utilization employing root crops, to lead to a depletion of the fertility of the soil. Again, in Japanese agriculture, as we have noted above, an intensive form of land utilization was employed in which the land produced a crop every year and in many cases two crops per year (both of grain crops and other crops), and the necessity of summer-fallowing was dispensed with by means of frequent hand-hoeing and hand-weeding while the plants were developing. Consequently it was natural that a heavy consumption of plant nutrients should take place, and, the supply of fertilizers produced on the holding was not sufficient to compensate fully for this consumption of plant nutrients.

No radical change occurred in this cropping system after the Meiji Restoration. If anything, the tendency was in the direction of an even greater intensification of cultivation on the minute holdings in an endeavour to expand the production of commercial crops. The area planted to wheat and barley grown as winter crops alternating with summer rice was expanded, while on unirrigated land as many commercial crops were grown by intercropping or companion cropping method, as could be fitted into the condition of time and space, and multiple cropping was extended even further. Artificial pasture grasses and feed-crops, however, were not introduced into Japanese agriculture on any scale, and on the whole the tendency was rather for the excessive emphasis on grain crops to be strengthened, the proportion of the total cultivated area occupied by grain crops being increased by such means as the expansion of the area planted to wheat and barley.

In this way the fertility-depleting system of successive grain-crop cultivation which characterized Japan during the feudal period was carried over essentially unchanged into modern times, and further, was strengthened all the more. This resulted in the aggravation of the tendency to deplete the soil within the individual holding, creating a demand for commercial fertilizers produced outside the holding. At the same time, the increasing of the supply of fertilizers to meet this

demand led peasants to adopt the use of fertilizers, resulting in the furthering of the development of the fertility-depleting system of land utilization. This line of agricultural development, in which soil depletion and the supply of fertilizers from outside the holding mutually promote one another, has been continued down to the present time.

## III

In the above we have given some account of the motives which led to the adoption of large applications of fertilizers in Japanese agriculture, concentrating our attention on the contrast between Japan and Western Europe. However, we may point out the following characteristics of the process of the adoption of heavy applications of fertilizers which was brought about by the availability of chemical fertilizers.

### *1. Increased Applications of Fertilizers to Grain Crops*

Considered as a whole, the process of the adoption of heavier applications of fertilizers in Japanese agriculture possesses the characteristic of being a process of the adoption of heavier applications to grain crops. This does not merely reflect the dominant position of grain crops in Japanese land utilization, for heavier applications have been made directly to grain crops, especially rice.

If we may again make a comparison with Western Europe, at the stage of successive grain crop cultivation under the three-field system which we have described above, applications of fertilizers were, of course, applications made for the benefit of grain crops, but such was the method of application that the fertilizers were not applied directly to the growing crop, but were applied, as described above, during the fallow period which occurred once every three years. The fallowing process was carried out not only for the purpose of getting rid of weeds, but also for the purpose of strengthening the soil fertility for the sowing of a following crop of wheat.

The transition from the three-field system to the modern crop rotation system resulted in a succession of crops in the order H–B–H–B through the introduction of artificial grasses and root crops. Thus the fallowing of arable land was replaced by the planting of these so-called "fallow crops." The ample supplies of dung produced from the greater quantities of feed grown under this system were applied chiefly

to these fallow crops (B), and the grain crops (H) which followed them had their yields increased by the residual effect of these fertilizers.

We may entertain the following reasons for this. The grain crops are crops which are relatively subject to limitations in effective fertilizer application, and if these limits are exceeded there is a danger that the application of fertilizers will cause the plants to topple over, and will have a catastrophically bad effect on yields. In contrast, as root and feed crops have a great capacity for absorbing fertilizers, there is no danger of the plants toppling over as the result of heavy applications, and their response to a heavy input of fertilizers is great. Further, fertilizers applied in large quantities, especially organic fertilizers, remain for some time in the soil (this being dependent on the combination of fertilizer application with deep ploughing, as we shall show below), and they thus prepare suitable conditions of soil fertility for the following crops, free from any danger of the plants toppling over, and provide good conditions for the raising of yields. At the stage of the three-field system in Western Europe the low productivity of grain crops was caused, not only by the insufficiency of the dung transported from the natural pastures, but also by certain considerations which made it impossible to develop the productivity of grain crops to the full, for even if attempts had been made to utilize large areas of pasture and to apply dung in large quantities, such heavy applications would have been attended by the danger of causing these broadcast-sown grain crops to topple over. Under the systematic rotation system the productivity of these crops was greatly improved because the limits of fertilizer application were mitigated by the effect of the previous root crops and because of the transition from broadcast sowing to cultivation in drills. However, the direct application of fertilizers to grain crops was not greatly increased, and what eventuated was the supply of nutrients to grain crops by means of the residual effects of increased applications of fertilizers to root crops. In this sense, the grain crops may be better described as having become "unfertilized crops" dependent on the residual effects of fertilizers applied to root crops. It is nevertheless true, as we shall show later, that in these cases the fertilizers applied were chiefly dung, and the application of fertilizers had important connections with tillage.

In contrast, in Japanese agriculture heavy applications of fertilizers were applied to the growing crops and consisted chiefly of quick-acting chemical fertilizers, and since the fertilizers were applied directly to the crops the application of fertilizers was liable to reach the limits

of fertilizer-absorption, and in particular to make the plants topple over. Further, the chemical fertilizers applied to grain crops in Japan, and especially to rice, were in the vast majority of cases nitrogen fertilizers, while potassium fertilizers, such as those used in Western Europe, which produce strong straw, were little employed, so that plants whose growth had been accelerated tended to have weak straw and were liable to topple over easily. It was because of this situation that, during and after the Meiji period, Japanese agricultural science concentrated its main efforts on a change-over to crop varieties which would absorb large amounts of fertilizers——on the improvement of high-yielding varieties which would absorb large amounts of chemical fertilizers and replace the traditional varieties then in use——and a large number of improved varieties was produced. A rise in rice yields was brought about by the combination of these improved varieties with heavy applications of fertilizers.

A heavy investment in chemical fertilizers was encouraged by the change-over to these new fertilizer-absorbing varieties, and at the same time technical improvements were made which raised the efficiency of fertilizers by improving methods of rearing healthy seedlings and methods of fertilizer application. The relations among these developments may be set out very schematically in the form of a cycle in which the technology of improving the absorption capacity of fertilizers by producing new crop varieties (C) and the technology of advancing the efficiency of fertilizers (E) act upon one another so that, when an advance on the one side reaches its limit, an advance in the other form of technology is promoted. This course of development may be represented by the formula $C \rightarrow E \rightarrow C' \rightarrow E' \rightarrow C'' \rightarrow E''$.

It was largely in this manner that the Japanese peasantry carried out their increased investments in fertilizer with the aim of raising as much as possible the yields per unit area on their minute holdings, and the process was pressed beyond economic limits to the biological limits of the rice-plant. Because of this, it frequently happens that slight meteorological changes, for example, in temperature or in hours of sunlight, cause the plants to topple over. We may say that phenomenon of rice laid flat, one which can be observed in many places during the ripening period of rice in autumn, is principally due to excessive applications of fertilizers (in cases where it has not been caused by storms, floods, and similar natural disasters). Such flattening of the crops is, of course, fatal for harvesting by combine harvester or similar machinery, but in Japan, where harvesting is carried out by

means of the sickle, it is thought to be a sign of a good harvest if the crop topples over during the ripening period. However, behind these facts there is a tendency for fertilizers to yield diminishing returns, as we may see from the calculations made by a famous Japanese agricultural scientist which indicate that the effect of fertilizers on crops in Japanese agriculture (the ratio between the amount of nutrients contained in the crop plants and the amounts supplied in fertilizers) began to decline sharply after about 1925 in the case of nitrogen fertilizers, and that before the late war, about 1940, only about 60% of the nitrogen supplied in fertilizers was absorbed and utilized by the plants. It may be supposed that this ratio has further declined as a result of the heavier applications of fertilizers which have been made since the war.

*2. Increased Applications of Fertilizers on Shallowly Tilled Soils*

The question of the manner in which tillage is carried out arises in connection with the application of fertilizers. The application of fertilizers is carried out for the purpose of providing plant nutrients which can be absorbed through the roots of the plants, and this is connected with the fact that, by means of tillage operations, the soil is brought to a swollen and soft state, and conditions suitable for the absorption of plant nutrients and the development of roots are created by aerating the soil and increasing its permeability. There are many technical problems in the tillage processes in Japanese agriculture, but in the present instance it is proposed to give special consideration to the problem of the depth of tillage.

In general, crop plants are divided into deep-rooted and shallow-rooted plants, according to the amount of vertical extension of the roots into the ground. In principle, the depth of tillage should vary with the depth of the roots of the crop plants, but the depth of tillage, in so far as it is an aspect of technology affecting production, should rather be determined with reference to the limits of productive efficiency, and should not necessarily vary in direct proportion to the biological development of the root system. It should be possible to divide crop plants, for the sake of convenience, into deep-tillage plants and shallow-tillage plants on the basis of the productive efficiency of greater or lesser degrees of depth of tillage. Grain crops may be said to be comparatively shallow-tillage plants. In contrast, root crops and feed crops are deep-tillage plants since, in general, their productive efficiency cannot be fully exploited unless the soil has been brought to

a swollen and soft state by tillage to a depth which will allow the full development of their root systems. Consequenly, the rotational system of agriculture, in which root crops are introduced into the arable land, presupposes deep tillage. In the establishment of the rotational system of agriculture, not only was the appearance of the drill and horse-hoe of great significance, as mentioned above, but also the change from the large-scale, heavy, wheeled plough which had been widely used in tillage in the Middle Ages to the light and easily manœuvrable modern swing (or wheel-less) plough. Since the mediaeval wheeled plough was heavy and bulky a great deal of animal-power was needed to pull it, and for this reason ploughing in the Middle Ages was usually carried out by teams of 4-6 animals, and the operation had to be performed on a communal basis. In general, shallow tillage was practised, except during the summer fallowing. However, after the invention of the swing plough it became possible for one man to operate the plough with one or two horses, and at the same time the adjustment of the depth of tillage was made easy. In this way it became possible for root crops which had hitherto been cultivated in garden plots tilled deeply with the spade to be grown in large-scale fields tilled deeply by the swing plough, and with the combined use of the increased supplies of dung produced under the rotational system of agriculture employing this form of deep tillage the efficiency of the new technology was exploited to the full. Further, the dung mixed into the soil by such deep ploughing not only provided good conditions for the growth of root crops, but a part of the plant nutrients remained, in the form of humus, in the soil for several years, while the physical nature of the soil was improved (formation of granular structure, etc.), and a rich tilth provided for the full development of the roots of the following crops. Consequently, even if the ploughing which preceded the sowing of the following crop were done only to a shallow depth it would still be possible for the roots to extend down to the lower layers of the soil, and, by utilizing the rich stores of residual dung contained in these layers, to produce high yields.

In contrast, in the Japanese agriculture of the feudal period which preceded the Meiji Restoration, tillage was carried out by means of the hand implement called the *kuwa* (Japanese hoe), and in general the soil was tilled shallowly. In certain localities ploughing with a single ox was carried on, but the Japanese plough at this period was the so-called "long-bottomed plough," which tilled the soil only to a shallow depth. With the increased use of multiple cropping which

followed in the Meiji period and later, ploughing was carried out with greater frequency, but there was a tendency for the ploughing to be done to an even shallower depth in the effort to hasten the process. This is exemplified in the four reasons for the low productivity of Japan's agriculture in the Meiji period advanced by Fesca: (1) Shallow tillage, (2) Imperfect drainage, (3) Lack of fertilizers and the high price of fertilizers, and (4) Mistaken systems of rotations. Among these, we have already discussed points (2)–(4). On the subject of point (1), shallow tillage, Fesca contrasted the depth of tillage for grain crops in Japan at this period, which was in general between 3 and 4 *sun* (9–12 cm), and the usual depth of tillage in his native country, Germany, which was between 5 and 6 *sun* (15–18 cm), while in the case of root crops, etc., the soil might be tilled to a depth of 1 *shaku* (30 cm). As one of the reasons for the shallowness of tillage, Fesca pointed out the structural deficiencies of the traditional Japanese plough. After Fesca, Japanese agricultural scientists also emphasized the necessity of deep ploughing, using the more powerful horse instead of the ox, while at the same time a number of improved ploughs were invented which made deep tillage possible, and horse-ploughing was adopted throughout Japan. However, among the peasants who actually used the plough, the plough was used as a means of reducing the time spent in the tillage operations required by multiple crop agriculture, and was valued more for its speed in carrying out tillage than for the depth of tillage which the improved ploughs made possible. There were not a few localities in which the depth of tillage was even less than it had been in the days of hand-tillage.

Thus we may say that the increased use of fertilizers in Japanese agriculture since the Meiji period was superimposed upon the traditional shallow-tillage technology. This is connected with the fact that no change was made in the system of successive grain cultivation which Japan inherited from the feudal period, either during the Meiji period or later, and that, on the contrary, Japanese agriculture developed in the direction of a high-level development of its grain-crop centred system of land utilization. Not only had it never been necessary for grain crops to have the soil tilled to the depths required by root crops, but increased applications of fertilizers, especially chemical fertilizers, were, if anything, better suited to the shallow-tillage technology. That is to say, the immediate availability of the nutrients directly supplied to crops by inorganic and quick-acting chemical fertilizers had a better effect on the plants when employed in shallowly-

tilled soil. In general, in Japanese agriculture not only are fertilizers applied immediately before sowing, rather than being applied to the land some time beforehand, but they are also applied during the course of the development of the plants as "supplementary fertilizers," and the technique of supplementary fertilizing possesses considerable importance.

Further, in this form of agriculture, characterized by shallow tillage and frequent after-tillage during the development of the plants, the oxidation and decomposition of organic fertilizers such as dung are liable to be accelerated, and under the summer conditions of a humid Oriental climate slow-acting dung fertilizers decompose rapidly and assume the character of quick-acting fertilizers, so that there is practically no residual effect in the following year. The consequence is that large quantities of fertilizers must be applied each year, for the shallowly tilled soil has little capacity for retaining fertilizers, and the greater part of the nutrients unabsorbed by the plants are not stored in the soil but leached away. This wastage of fertilizers is particularly marked in unirrigated land. On irrigated land a certain level of rice yields is assured, even without fertilizer application, provided that the land is amply supplied with water, for, as we have noted above, natural fertilizing substances are supplied in the irrigation water, and the majority of Japanese rice fields are located in areas of alluvial soils of comparatively high fertility. However, heavy direct applications of fertilizers must be made if yields are to be raised. Again, Japanese agriculture includes the utilization of unirrigated land for the cultivation of root crops, etc., as in the combination of grain crops and potatoes or sugar beet (principally in Hokkaidō). In these cases the depth of tillage is of the order considered suitable for grain crops in Europe, and since the depth of tillage is not sufficient for the root crops, the fertility-promoting character of these crops in combination with intensive fertilizer application is scarcely made manifest, and they are nearer to the fertility depleting grain crops in character. Again, in the case of leguminous crops such as soybeans the direct effect on the nitrogen content of the soil is not very marked, and they resemble the grain crops in that they are analogous to the beans and peas frequently grown in place of spring crops (especially oats) under the Western European three-field system, which were of a fertility-depleting character.

Thus, not only is it impossible to exploit to the full the special characteristics of deep-tillage crops when these are grown in shallowly-

tilled soil, but the relative profitability of combining deep tillage with heavy fertilizer application is also decreased. This is revealed in the fact that, in Japanese agriculture, heavy applications of fertilizers took the form of relatively heavy applications to grain crops which had little capacity for fertilizers, and relatively light applications to root crops, etc., which had a large capacity for fertilizers. In this respect, we may say that the differences between crops in regard to the amounts of fertilizers applied were much less in Japanese agriculture than in the agriculture of Europe and America. For example, in America chemical fertilizers are applied to almost 80% of the area used in the cultivation of potatoes and sugar beet, while they are applied to only 20% of the area used for the cultivation of wheat, and the amounts applied per hectare are only about 1/6 of the amounts applied to root crops. In Japan, not only are fertilizers applied to practically all crops, but there is scarcely any difference between the amounts applied per hectare to root crops and the amounts applied to rice——although the amounts applied to rice are relatively heavy among grain crops. Again, the application of larger amounts of fertilizer to hay crops than to wheat, which occurs in America, is something which has not yet been used in Japan.

## IV

As we have shown above, Japanese agriculture increased its productivity by means of a vast investment of chemical fertilizers, but this increase in productivity was chiefly restricted to irrigated rice, and the productivity of other crops increased only by small amounts. In particular, the relative inferiority of Japanese agriculture is conspicuous when comparisons are made with the increases in crop productivity which have been effected since the war in the countries of Europe and America as a result of an increased consumption of chemical fertilizers. That is to say, we have grounds for thinking that increased applications of fertilizers in Japanese agriculture, operating as they do on land subject to shallow tillage, have now almost reached the limits of their effectiveness, it being granted that there are some regional exceptions to this. At this juncture we may suppose that a great turning-point in the productivity of the land in Japanese agriculture will be constituted by the change-over from the technology of heavy fertilizer applications on shallowly-tilled land to

the technology of heavy fertilizer applications on deeply-tilled land. This is exemplified in concrete terms by the fact that the prize-winners in the rice-yield contests which are held every year are invariably peasants who have employed the technology of heavy fertilizer applications on deeply-tilled land, and further, large quantities of dung have been included in the fertilizers which they have invested in the land. As these examples show us, it is proved that in Japan, too, a marked all-round improvement of productivity can be effected by a combination of deep tillage and heavy applications of fertilizers, particularly of applications of dung as an organic fertilizer, but the methods employed in producing these results are not necessarily rational from the economic point of view. The holdings in question are situated in areas which possess ample resources for the production of organic fertilizers in the form of natural grasses, and much greater amount of labour is invested in the holdings (not only in the tillage and cultivation of the high-yielding irrigated rice fields, but also in weeding, fertilizer application, etc.), than on other holdings, so that these high yields may be regarded as having been produced at the expense of an excessively high investment of labour.

A high rate of labour-investment of this kind, which has been the support of Japanese agriculture in the past, has become almost impossible in recent years as a result of the efflux of the younger men from farming villages to the cities, and agricultural operations are in process of transfer to the labour of women and old persons. In response to this labour shortage there has been a marked increase in the purchases of garden tractors in recent years, as we have noted above, as well as of large-scale tractors purchased with the aid of government subsidies. What degree of economic efficiency can be attained by mechanized agriculture employing large-scale machinery, such as the form of agriculture represented by these tractors, is a problem for the future, but the immediate effect produced by the introduction of tractors is the fact that the transition to deeper tillage is being made easier. That is to say, the shallow-tillage technology which is traditional in Japanese agriculture is being gradually broken up by the adoption of the tractor, and the possibilities of a transition to a deep-tillage technology are being enlarged. We may say that this has an epoch-making significance in that it is a transition from the technology of heavy fertilizer applications on shallowly-tilled land to the technology of heavy fertilizer applications on deeply-tilled land.

However, a problem which arises at this point is the fact that the

supply of the dung which is the fertilizing agent applied effectively in combination with deep tillage is on the decline as a result of the replacement of animal power by machinery and the decline of the small-scale rearing of animals for slaughter which has been carried on as a means of supplementing the family budget.

In this situation, we may say that the key to the future of land productivity in Japanese agriculture is to be found in promoting soil fertility through deep tillage. In order to accomplish this, the area of the holding must be enlarged.

By enlarging the scale of farming, we can solve both the problem of raising land productivity through increased soil fertility and the problem of raising labour productivity through the mechanization of agriculture.