BREEDING METHODS OF POTATO
AND
PRODUCTION OF SEED POTATO

November, 1978

JAPAN INTERNATIONAL COOPERATION AGENCY

AGRICULTURAL DEVELOPMENT COOPERATION DEPARTMENT

BREEDING METHODS OF POTATO

September, 1978

Takamichi Chisiki
Director, Aino Potato Breeding Center
Nagasaki Prefectural Agricultural Experiment Station
Japan

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I. ESTABLISHMENT OF BREEDING TARGET

At the onset of anything it is important to clearly define its target. The same is particularly true in breeding because the breeding work requires many years of hard and patient toils Any mistake in the first establishment of that target the efforts of those many years, more often than not, end fruitless Because thereof careful study is required at the beginning by spending sufficient time to establish a definite target by forecasting future trend in demand

It is necessary to conceive various conditions for the establishment of target. To begin with, the use must be clearly defined. This use is not to simply consider the present use but the trend of future food life should taken into account and in accompaniment therewith possible change in cooking method should be incorporated in the plan. The next important matter is to comprehend the natural conditions of region in which potato is to be extended.

Potato is weak resistant to frost as well as to heat. However, it has a very excellent characteristics as short-term crop and ensures a large yield in central latitude temperate zone by utilizing short period for proper warmth. Accordingly, important matter in variety selection is to fully study the climatic condition and to know beforehand cultivation-possible period. Furthermore, another important matter is to fully comprehend the customary cultivation practice of the region.

Potato, as is well known, is being cultivated throughout the world and there are many famous varieties Each of those famous varieties has its own characteristics. And a fact that good varieties are being cultivated by choice means that the varieties are well suited to the cultivating type of that district. It must be remembered that very excellent variety being cultivated in A-district does not mean that it is always the best variety in B-district So customary practice or favorable cultivating type of the district concerned should be studied first and the right variety suited to that district selected.

Potato has many uses but the most important one is the food use. And the characteristics which are requisite as food use must have the qualities stated hereunder. However, which item among those qualities should be emphasized as important one differs by food habit and fancy of the people of that country. Accordingly, the selection must be made to comply with the actual circumstances of the country. And even in the same country the evaluation entirely reverses by cooking method. One salient example is the potato's hardness or ease against the crumbling-in-boiling. The color of potato preferred by people differs –

some prefer white fresh and others like light yellow, all depending on the people's fancy.

Now some explanations will be made on the breeding target.

1. Characters to be given Attention in Use

1) Outside shape of potato

The conditions to be complied with to appeal to consumers are: The size is appropriate and the eyes are shallow. Particularly, the eyes' shallowness is an important factor because it is deeply related to the difficulty in peeling. And smooth skin is generally preferred.

2) Starch value and crumbling-in-boiling

The taste of potato is determined to certain extent by starch valve. When starch valve is too low potato becomes watery and the taste is poor. Conversely too highly starch value results in poor taste. Thus, proper starch valve is an important factor The crumbling-in-boiling has a positive correlation to starch value The higher the starch value the easier the crumbling-in-boiling The evaluation of this character differs by cooking method.

3) Colors of skin and flesh and taste

The skin color greatly varies from white to deep purplish red Because of people's taste no decision can be rendered as to which color is the best. In general those in white, yellow or light brown colors are being preferred Many varieties have white or yellow flesh but as stated above it is a matter of fancy

The evaluation of taste is a difficult character but good taste is an important condition.

4) Sugar content and discoloration after cooking

High-sugar-content potato when fried produces the charring resulting in ill-favored dish. A variety with low sugar content and variety which does not produce sugar content even under low temperature is preferable.

The discoloration after cooking means a phenomenon where potato soon turns blackish after the boiling. As for its cause various studies are being reported but it is well known that the phenomenon differs greatly by variety.

5) Content of vitamine and protein

Potato highly contains vitamine. Moreover, it has been said that vitamine in potato is stabilized against the heat. However, the supply of vitamine C is also available from other sources that as to whether the intake of vitamine C should be dependent on potato or not must be determined by taking into account of food habit.

As for the content of protein both in quality and quantity it is one of the recent research problem in breeding. Particularly as to its quality there are several reports However, this should also be examined in connection with food habit and determined whether to take it or not

6) Central cavity and inside's deterioration by disease

Despite a fact that these two characters are big headache in food use the trouble is that those abnormalities can not be detected from outside. And those two phenomena do not outbreak at all times, but certain conditions such as drying or deficiency of some microelements promote their outbreak.

2. Target's Characters from the Standpoint of Cultivation

1) Dormancy period

Because potato cultivation heretofore has been developing centering around high latitude cool region it was a single crop a year. Thus dormancy period presented no problem. And even in central latitude region varieties have been selected on the premise that seed potato is available from high latitude district or high-elevation district However, now varieties characterized by early-period-highly-enlarging and short-dormancy period have been bred making possible two crops in spring and fall Because thereof continuous cultivation became possible by acquiring variety selection technique and by using such selected varieties it is no longer necessary to procure seed potato from other regions. So as a direction for future it is a very important problem whether to cultivate a single crop a year in spring or two crops a year in spring and fall by using short-dormancy varieties.

2) Response to fertilizer (fertilizer resistancy)

It is a well-known fact that nowadays the application of chemical fertilizer is widely fashionable throughout the world. And many varieties have come to exhibit ability of high response to heavy application of chemical fertilizer. Accordingly, fertilization condition

should be fully studied under the actual cultivation and by giving due consideration to the availability of fertilizer Wihtout such studies wrong conclusion might results

3) Resistancy to diseases and insect pests

Virus diseases and other bacterial diseases cause a great damage even in high latitude regions where general resistancy to diseases are being studied. However, because the aspect of disease damage outbreak differs by prospective potato cultivating district and district where potato has been produced reexamination should be made on major diseases of prospective district, particularly on Bacterial wilt. Powdery scab which does not cause so much damage in low temperature district but plays a havoc in warm district

4) Day length and reaction against the atmospheric temperature

These two factors present no problem in one crop district but they are important factors for the cultivation in spring and fall. The formation of tuber in potato cultivation is poor when the day length becomes long and atmospheric temperature becomes high. On the other hand, a trend in day length and atmospheric temperature becomes vice versa in spring and fall. And the varieties which react sensitively to such conditions a balance of yield for spring and fall cultivation is not favorable.

II. FINDINGS FROM THE VARIETY SELECTION TEST

1. Collection of Test Materials

The very first procedure in selection test is to start the collection of test materials Because potato is widely cultivated the world over many test materials are available from many countries. In the case of importing potato from abroad for food or seed uses the very important matter is a problem of plant quarantine There are many injurious disease and insects in potato that if some of them are allowed to invade into disease-free region it would be irrevocable. In Japan after lifting the import ban on potato after the end of the last World War some malignant diseases invaded the country and great damage is still being sustained. Recently the invasion of Cyst nematodes into Japan has been permitted by accident causing a grave problem. Because there is no definite control measure for those major diseases the prevention of invasion is the best counter measure Interception at the port of entry is one of the most effective controls.

The next important matter is a measure for seed potato Disease damage in potato in most cases propagates by seed potato and because progress in disease infection is fast the supply of disease-free, healthy seed potato is very difficult without the establishment of seed collection system In parallel with the progress in disease infection the productivity declines Because thereof there arises a necessity to import healthy potato at all times, and even superior varieties have been selected there still remains a problem whether or not a smooth supply of seed potato of superior varieties is possible Under such a condition the very first requisite in variety selection is the stabilized supply of seed potato rather than superior variety. It is regretable but it is true. So if potato cultivation is to be pursued in any country the urgent need is to establish seed collection system of its own. The next important matter is the selection type and dormancy period, the both being related to the present seed collection system. As it is generally known, potato must have a certain period of dormancy after the harvest And during this dormancy period it is not possible to cause the germination under ordinary method. And after the termination of dormancy period the eyes' elongation commences and as it progresses the value of potato gradually declines not only as food use but as seed. And the higher the atomospheric temperature the faster is the progress in quality's decline.

Accordingly, in warm region either two cropping a year is adopted or unless seed is procured from high elevation district of same condition as cool district, otherwise cultivating type and dormancy period are not adjustable. Thus, it becomes inevitable to purchase seed potato.

Seed potato is characterized by a general trend that tuber formation accelerates, stem number increases, the number of potato per hill increases and weight per potato becomes lighter in proportion to the length of period after the end of dormancy period

2. Method of Productivity Examination Test

In the productivity examination test it is convenient to carry it out in two stages – main test and preliminary test.

Preliminary test is a stage where a rough selection is made on many test materials to select superior strains which are to be used at the next productivity test. Accordingly, in this test the stress is not on the yield but on such characters as colors of skin and fresh, depth of eye, length of side branch and starch value. Because there are so many number of test strains it is not necessary to make test plot acreage so large. And the number of repetition needs not be more than 2 – 3 times. A variety which can be used for comparison or as standard is introduced among the planted test mateirals and with the characters of this introduced variety as reference the superiority of test strains is judged

The productivity examination test is a test to render a final judgement on the superiority of strains selected as superior from among those prospective varieties selected under preliminary test. At this stage because it is necessary to judge the quantitative character such as yield a full care must be given to the test's accuracy. As to the details of field test it will be explained in Chapter III. When the yearly errors are considered, the same test should be repeated continuously for 3 years at least. Otherwise, it is difficult to obtain definite conclusion. And when the natural conditions such as climate and soil of the region greatly differ unless test is carried out by respective district there arises a danger of inviting a wrong conclusion. And in this case the planting, harvesting period, planting density and fertilization volume must be in accordance with the rational and general ways as practiced in the district.

3 Specific Character Examination Test

General superiority of vareity can be determined by the productivity examination test stated above but as for specific character's superiority it requires separate test. And the same is called specific character examination test.

In this case specific characters are defined to mean various characters under cultivating conditions and selection target in the region such as fertilizer resistancy, disease resistancy to Bacterial wilt. And among those characters resistancy to general diseases and insects can be judged to certain extent from the origin of potato but for the disease and insect damage

peculiar to that region it is necessary to carry out a test by himself. Particularly, because there are many diseases and insects in central latitude regions which can not be found in high latitude region this test is highly desirable. Specific character examination test on disease and insect should be repeated several times to obtain correct information because there are many cases where artificial control of disease outbreak is difficult.

As for test method, in the case of Bacterial soft rot comprehensive judgement must be rendered from several tests on natural outbreak of disease under field test, disease outbreak condition by soaking potato into the zoospore solution or disease outbreak condition by inoculating virus into potato. According to test item if the right place is selected where its specific character can be most easily discovered a great result can be obtained in many cases For example, in the test for disease resitancy the best result can be obtained by carrying out a test in place where the disease outbreaks easily each year and for Powdery scab and Bacterial wilt construct a small field infected artificially by virus and cultivate potato therein.

III. FIELD TEST

1. Reasons for Error in Field Test

In order to determine the superiority of variety the best method is to cultivate under the cultivation method generally practiced in that district. There are many examples where A-variety is superior or B-variety indicates a better result by cultivating place and by year. And several factors can be conceived for the fluctuation value obtained under such a way but major reasons are as follows:

1) Fluctuation by climatic condition of that year

Needless to state is a fact that crop grows and produces dry matter by nutrition obtained from the soil and by the sun's energy received by palnt above the ground that the growth and yield are naturally influenced by weather of that year. Climatic condition differs by yeat and how that influence is received by plant differs by variety and yearly fluctuation does not take the same trend. Because thereof in order to determine the superiority of variety the same experiment must be repeated for 3 years at least and based upon the findings therefrom comprehensive conclusion should be rendered.

2) Error produced by lack of uniformity in test field

First of all, the whole of a plot of upland could not be uniform. There are differences in the depth of cultivating soil, dryness or moisture of soil, sloping direction of land and sloping degree and the same influence the productivity and also produce errors And the removal of such errors is possible to certain extent by soil dressing, by making the depth of cultivating soil uniform or by uniformalizing the land's sloping direction but complete uniformalization is impossible So the test in land's uniformity is carried out to find out the difference in soil fertility and direction of soil fertility. Then from the degree of error's fluctuation test farm is plotted into block by sloping direction of soil fertility and differences in soil Fertility Then block's size is decided By such way those errors can be removed to large extent.

3) Error from competition

This kind of error can be classified into the error within the test plot and error among the test plots. The errors within the test plot are the errors caused by non-uniformity of space occupied by each hill caused by missing plant and different space between plants. To remove this error the weight of seed potato should be made uniform befor planting and plant-

ing density is to be made exact and to eliminate missing plant. Competition among the test plots is produced by the differences in grass type of adjacent varieties and difference in cultivation easier and in such a case plant growth at the outskirt is more vigorous than the plants inside because more space is available to the outskirt' plants This phenomenon is called specially as border effect. The degree of border effect and the sphere influenced thereby differ by kinds of crop and cultivation method and by excluding these parts from the investigation this kind of error can be eliminated

2. Size of Test Plot and Number of Repetition

The size of test plot is determined by various conditions such as kind of crop, purpose of test, number of test material's strains, acreage of farm and available labor force, etc. For the small-grain crops like rice and barley comparatively small acreage will suffice because individual variation is small. In comparision therewith sweet potato and potato require more acreage because individual variation is large.

The larger the acreage of a plot and the more the number of repetition the smaller is the error, but when plot acreage becomes too large the error created by plot's non-uniformity becomes larger and the precision declines conversely. The number of repetition will be controlled by labor availability and field acreage, so that field acreage can not be increased unlimitedly. If the acreage of test farm is fixed the acreage of a plot can be made a smaller and by increasing the number of repetition the error can be minimized. However, attention should be paid to a fact that indiscreet increase in plot acreage would invite a larger error In the cultivation method hand operation can achieve more accurate result. The use of large farm machinery invites a decline in precision inviting an easy entry of error. Here at our Potato Breeding Center in Nagasaki prefecture no large farm machinery is used. All farming operations and harvesting are carried out by small-type machineries and 7 – 8 HP garden tractor. A plot of 6 m^2 with 3 repetitions bring about satisfactory data In other experiment stations throughout the country general practice in experiment use 5 10 m^2 plot with 3 – 4 repetitions. In the United States a large blot of 150 m^2 was used in former times but according to recent report a plot acreage has been reduced to 10 – 32 m^2 with 4 – 5 repetitions The shape of test plot of near square is desirable from the standpoint of reducing the local variation within the test plot, but from the standpoint of management operation and observation and rectangular shape near square is convenient.

3. Arrangement of Test Plot

The field test is indispensable in any breeding work. Breeding work's field test differs from physico-chemical experiment carried out indoor and at factory in that field test is subject

to various limitations And the main limitation is the error caused by non-uniformity of farm conditions and in most cases only one test a year is possible that varieties' reaction to climatic conditions are not the same

Such an error can not be completely removed by uniformalizing the plots and by trying to make the test operation as precise as possible. In reflection thereof a theory has been established by R.A. Fisher for test plan which advocates proper establishement of test plan, thereby computing the differences in soil fertilities and various test errors and based thereon the magnitude of test error is judged as to whether the difference among the varieties or among the treatments are intrinsic or simply an accidental difference. This method has achieved a far reaching progress by the efforts of many researchers since then. Practically all countries of the world carry out the experiment under the application of this theory. To effectively carry out this kind of test the uniformity trail should be carried out first, in which it is necessary to investigate the magnitude of test error which have resulted at the time of the test carried out under various forms and acreages. Passing through such a procedures the most effective size of test plot, direction of block and required number of repetition are determined.

The methods used widely in breeding test will be mentioned hereunder but to mention in full details the space is limited in this paper, and as there are many publications on this subject it is requested that those publications will be used as reference.

1) Voluntary design method

This method is not a test method based on the test plan method mentioned above but it is convenient in making preliminary selection from among many test materials. The salient feature of this method is to plant any standard variety under fixed plan beforehand and in between the same unknown variety is planted. And this procedure does not fullfil the random nature which is a precondition for test plan method. The investigation is to evaluate the unknown varieties planted in between to compare with numerical value of the standard varieties Although this method is not very useful to evaluate quantitative character but it is fully useful in the evaluation of qualitative characters of varieties collected from various districts at the stage prior to the productivity-examination-preliminary-test.

2) Completely random design method

It is the simplest test plan, a method to repeat each treatment on test material several times. The number of repetition needs not be always the same. As the diversion analysis table is self-explanatory all those other than treatment effect are disposed as error items, so that degree of freedom of error becomes larger but in the case of field test unless uniform-quality

farm is available the error's magnitude becomes large. So it is not suitable in large-scale field test. It is effective in pot test and indoor experiment

Sum of squares of the whole = Sum of squares of treatment + Sum of squares among the repetition within the treatment (Sum of squares of errors)

3) Randomized block method

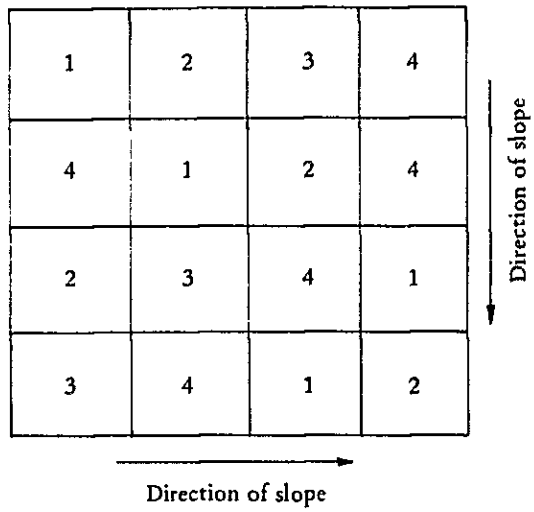
It is a test method most widely used. This method is to prepare the number of repetition for block which are recognized as having uniformity in soil fertility and other conditions and each block thereof is divided into small plots to match the number of treatments (varieties) on which each variety is arranged at random. In this case each block needs not always be adjacent to each other, but uniformity should be maintained within each block. In this case diversion analysis is as stated hereunder and becasuse the variation among blocks can be removed by computation, thus degree of freedom of error becomes smaller than that of completely random design method but the test precision improves that much. Moreover, because uniformity must be maintained as much as possible within the block, upon increasing the number of treatment too much the acreage of a block becomes too large causing difficulty to maintain uniformity, thus it is not desirable.

Sum of squares for the whole = Sum of squares of treatment + Block's sum of squares + error

4) Latin square method

It is an arrangement method of good effect when the number of test material is not so large and in case soil fertility is estimated to be either obscure or complicated. The number of test is prepared by square-multiplication of the treatment (varieties) to be used for test and each treatment is allocated to block of two direct directions and the arrangement is so carried out that all treatments are included always in each row and line. (See Graph) Because thereof when the number of treatment is small the degree of freedom of error becomes small and degree of precision declines. Conversely, when the number of treatment is too large farm's acreage becomes too large which often invites the increase in error or making the test impossible. From such a situation it is mostly used when treatment plot is around 5 – 8. Dispersion analysis besides the effect of block stated above it is possible to compute and remove one other block which goes straight through the same that precision degree improves that much.

Sum of squares of the whole = Sum of squares of treatment + Sum of squares of line + Sum of squares of row + Sum of squares of error



5) Split plot design method

All the tests hereinabove mentioned are the tests with one treatment (variety) as object. However, there are many cases where it is desirable to make test by combining two factors such as productivity and fertilization volume or relation between planting density and variety. In such a case upon arranging each test plot under the Randomized Block Method not only the management becomes difficult by creating difference in fertilization volume in adjacent plot and in border width but often invites poor precision. In such a case this Split-Plot Design Method is very convenient. In this method a block is largely divided into main plot and small plot On main plot first factor is alloted at random and on small plot the second factors are arranged at random (See Graph). For instance, if productivity test is to be carried out on 5 varieties dispersion analysis is as stated hereunder by dividing levee width into three stages and by carrying out the repetition 3 times.

Factors	Degree of freedom
Block	3 - 1 = 2
Treatment (levee width)	3 - 1 = 2
Error (a)	4
Main plot	8
Variety	5 - 1 = 4
Mutual action	4 x 2 = 8
Error (b)	20
Total	5 x 3 x 3 - 1 = 44

As the above is self-explanatory the two kinds of error can be obtained and because the test precision is higher in varieties arranged in small plot as a rule, factors which are deemed as important are alloted to small plot but the arrangement should be made with due consideration to management's difficulty.

Split-Plot Design Method

Block 1

1	4	4
4	1	5
3	5	1
2	3	4
5	2	3
A	C	B

Block 2

5	3	1
1	2	4
3	5	3
4	1	2
2	4	5
C	B	A

Block 3

1	4	3
2	1	4
5	2	1
3	3	5
4	5	2
B	C	A

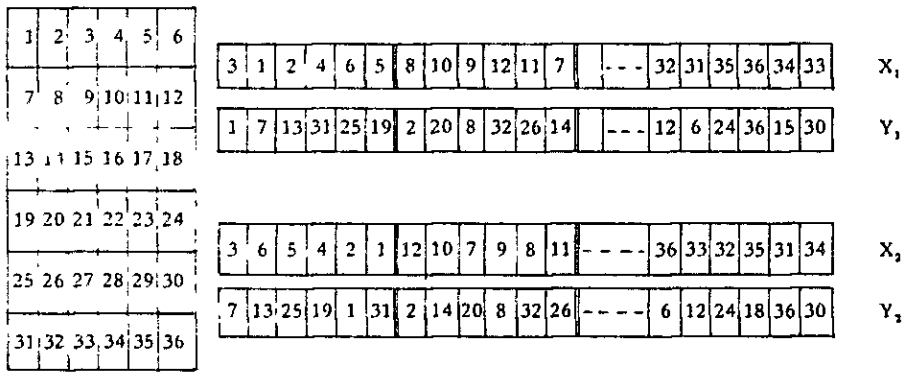
6) Simple lattice square method

In case the number of strains for test becomes too large it becomes impossible to use the Latin Square Method and Randomized Block Method becomes useless because the acreage of a block becomes too large which produces a larger error by non-uniformity of farm In such a case the number of varieties to be planted in one block should be limited and a portion of test varieties is used as a block This test method is the Lattice Square Method And the most simple one thereof is the Simple Lattice Square Method In the Simple Lattice Square Method the number of test varieties is squared, for instance, 25 (= 5^2) and 36 (= 6^2) and in case of surplus or shortage, comparative varieties are either added or reduced 50 it will become squared. For example, in the case of 6^2 = 36 it will be divided into x-group and y-group and the same are arranged at random as shown in Graph

Because the test is made by making such X-group and Y-group as a set repetition's number is usually 2 or 4.

Factors	Degree of freedom
Whole	6 x 6 x 2 x 2 - 1 = 143
Varieties	6 x 6 x 4 - 1 = 143
Block	2 x 22 (6 - 1) = 20
Component (a)	2 x (2 - 1) (6 - 1) = 10
Component (b)	2(6 - 1) = 10
Error within the block	(6 - 1) (2 x 2 x 6 - 6 - 1) = 85 (Ec)

Simple Lates Square Method



4. Investigation Items and Methods

To comprehend the characters of each variety investigation must be carried out and the result thereof should be recorded. In the investigation the first important matter is to select investigation items. And as many items can be mentioned for investigation but it is prerequisite to comprehend for what purpose that item is required, then obtain the required information and the findings should be recorded. Only a mere recording just simply the investigation item was there not only is a waste of time but invites poor result.

The next important matter is the establishment of investigation standard. To investigate any matter certain standard, needless to state, is requisite. But if that standard varies by year and by man's ability then mutual comparative study is impossible. So a fixed standard shoud be established always and in accordance therewith the findings should be recorded.

Furthermore, in connection with this standard attention should be given to the unit for investigation For instance, in surveying the length of stem decide whether it will be cm or mm. The measurement up to mm has significant meaning or not should be decided. And the yield is usually indicated by kg/ha. Determine beforehand what is an appropriate unit.

Now, some explanations will be made on investigation items and methods.

The table indicates general investigation items and standard used by us. Of course, all of those investigation items will not be carried out in all tests. Required items in accordance with the purpose of that test are selected and investigated According to some experiment detailed investgation standard is used. Particularly, there are many examples on disease damages. For instance, for the disease outbreak of epidemic proportion survey is carried out 1 – 2 times a week by classifying the infection's magnitude into 5 – 6 stages. Moreover, such items as the number of flowers to be investigated by observation decide beforehand the varieties to be investigated which will serve as standard because investigator's subjective point of view can easily enter.

As for the investigation on growth column-A should be emphasized on No 7 10, 12, 19 – 24 and other items are omitted in many cases And No. 1 – 6 are the items in case true seed has been used. In the case of No 25 – 27, if necessary, special investigation should be carried out for detailed study The yield survey of B is an investigation item directly related to practical character Only in the case of food use No. 10 is not necessary. No. 9 can be indicated by specific gravity As for the need of grade classification of No 2 – 5 such as 20 g, 60 g and 120 g should be examined in accordance with the state and custom of a country As for No. 12 – 17 they should be examined to make them more detailed or simplified by giving consideration to market's demand. Special investigation of C has a little connection to practical character so it can be omitted Furthermore, in No 3, 6, 7, 10, 13, 14 and 16 if the identification of varieties are recorded they are convenient in later days. As for No 32 classification of this degree is sufficient for varieties of one crop a year but in case it is directed to short-dormancy varieties more detailed differentiation is necessary. A publication, 'The Potato' by M.G. Burton mentions special characters but for special characters to be used need not be so detailed.

Some items in this paper are from the 'Description for the Cultivated Potato'. This is the standardization of varieties' characters compiled at the CIP and IBPGR conferance held in October 24 – 28. 1977 and are a draft upon the premise that they will be consolidated later by using computer. Among those items marks are the items desirable to be clarified at least up to this degree in the case of exchanging informations on varieties. This draft is to be further studied hereafter and consolidated as a definite plan It is added here as one of the criterion for the consolidation of varieties' characters.

PRODUCTION OF SEED POTATO

September, 1978

Dr. Satoshi Tanaka
Chief, Foundation Stock Seed Production Dept.
Tsumagoe Potato Foundation Stock Seed Farm
Ministry of Agriculture, Forestry and Fisheries
Government of Japan

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I INTRODUCTION

Seeds of potato are the tubers which are the developed subterranean stems. All virus diseases and some of the bacterial diseases such as ring rot and black leg are borne from the seed tubers All of those diseases are called tuber-borne diseases. The selection of healthy tubers is impossible by external appearance and it is also impossible to control the diseases by sterilizing the tubers Therefore, these diseases greatly influence the productivity of next generation. As all varieties of potato have dormancy period the physiological vitality in seed tubers is determined by whether or not seed potato have strong sprouting ability at the time of planting. From these facts productivity of potato is subject to the control of the seed's quality such as strong physiological ability and disease-free. The major objective of producing seed potato is to produce disease-free seed and to ensure stabilized supply of disease-free, high quality seed to seed growers.

Good seed potato must have the following characters: The seeds are free from all tuber-borne diseases, good sprouting ability, varietal characteristics and appropriate shape. And all those factors must be carefully considered prior to the introduction of seed from other region. Tuber-borne disease other than the above can be controlled by means of selection, sterilization and management during the growth.

Tuber-borne diseases are very difficult to control. The control is by roguing and by preventing the infection in the field. The most important purpose of seed potato production is to eradicate tuber-borne diseses.

II. POTATO DISEASES AND INSECT PEST

1. Virus Diseases

The control of virus diseases is the most important task in seed potato production. And there more than 30 species of such diseases out of which about 10 species inflict a far reaching damage to potato production. Diseased plants manifest various symptoms such as mosaic, yellows, necrosis, streak, leaf roll, dwarf and stunt. The decline in yield by virus disease is generally 20 – 30%. The damage sometimes causes as much as 70 – 80% losses in yield Infection in the field can be classified into two types. One is a transmission by contact or sap (juice). The virus's infection from diseased plant to healthy plant is by contact And virus also contaminate farm machinery and tool as well as cloth and animal. The virus is assumed to enter healthy plant through a wound Others are transmitted by vectors. Major vectors of the potato viruses are aphids, and thrips or leafhoppers On the other hand, soil-borne viruses are transmitted by zoospore of chytrid fungi and soil nematodes. This chapter intends to explain the important potato viruses and their diagnostic symptoms and manner of transmission.

. Viruses transmitted by contact

Potato virus X (PVX) = X mosaic

PVX widely outbreaks the world over. Particle is flexuous, normal length 520 μm and diameter 12 – 13 μm Infected plants with PVX appear mild mosaic, but necrotic lesions appear by severe strains. These symptoms usually appear intervein of the leaves (interveinal). When infected plants manifest no symptom, it is called carriers, and the variation of symptoms affected by virus strains or environmental conditions such as temperature. PVX is easily transmitted artifically by sap inoculation. It spread in the field by contact of leaves and roots and farm tools, cloth and animal.

Potato virus S (PVS) = S mosaic

PVS is widespread in commercial stocks. Particle is flexuous or rods, normal length 650 μm and diameter 12 – 13 μm. Infected plants manifest interveinal yellowish spots such as pinhole on middle or lower leaves, in many varieties mainfest mild rugosity, infected plants are also carriers by environmental conditions (at higher temperature 24°), and virus strains PVS is mainly transmitted by contact of leaves and roots, but this virus usually spreads slowly.

Potato spindle tuber virus (PSTV) = spindle tuber

This virus has the properties of free nucleic acid (double strand RNA) and called viroid. Symptoms of tubers show long spindly ones, after deformed in cracking. Symptom of haulm is usually slight. PSTV spreads by contact, by transfer on farm implements and some insect-like vecters such as *Lygus pratensis, Melanoplus* spp. and aphids.

Tobacco mosaic virus (TMV)

TMV does not usually outbreak in potatoes. Particle is rods, normal length 300 and 18 μm wide.

B. Viruses transmitted by aphid

Potato leaf roll virus (PLRV) = leaf roll

PLRV is also a disease common all over the world. It is the most economically importance in potato Particle is spherical, about 25 μm in diameter. This virus cannot be infected by sap inoculation. In the field it is only transmitted by aphids. *Myzus persicae* is the most important vector, other aphids that can tramit PLRV are *Aulacorthum solani, Macrosiphum euphorbiae, Myzus ascalonicus, Aphis nasturtii, Neomyzus circumflexus* etc. In transmission of the virus, the aphids must feed a long time over an hour on the diseased plants to acquire the virus, and to become viruliferous. But an aphid, once infected, the aphid can be transmit a life, so that this virus called as persistent transmission. The virus seems to pass from the intestine to the hemolymph or blood, and transfer to the salivary glands in the aphid, so that the term circulative virus is also used.

Secondary symptom of diseased tuber is usually the rolling of the lower leaves keep with the interveinal yellows. The size of a plant is smaller than a healthy one. Primary symptom from injections by aphid appear mainly in young leaves at the top of the plant, these leaves usually turn pale-yellowish or redish and often manifesting the rolling.

Fotato virus Y (PVY) = Y mosaic

PVY is widespread in potato Particle is flexuous, normal length 730 μm and diameter about 11 μm PVY is transmissible by sap inoculation, in the field is mainly transmitted by aphids The aphid acquires the virus by probing in seconds on the diseased plant, and the aphid can immediately transmit to healthy plant by probing, but soon loses its infectiveness either after the several hours or by probing healthy plant. Part of the aphid that transmitted the virus seems to be attached tip of the stylets. *Myzus persicae* is considered the most important vector for spread in the field. Other aphids are *Aphis nasturtii, Myzus ornatus, Macrosi-*

phum euphorbiae, Neomyzus circumflexus Symptoms of infected plant vary widely with strains and varieties. Mosaic type symptom is manifested generally on vein clearing of young leaves at first, then it shows mild mosaic or rugose mosaic. Streak type symptom causes veinal necrosis on old leaves at first, then it shows leaf-drop streak.

(Potato virus A (PVA) = A mosaic)

PVA is widespread in potatoes Particle is flexuous 730 μm long and about 11 μm wide. Infected plant is usually mild mosaic, thus it may seem less important than other viruses. But case in combination with PVX causes a severe damage, a disease known as potato clinkle. In combination with PVY, it also inflict a severe damage. PVA can be transmitted by sap inoculation, transmission in the field is mainly by aphids, and it is stylet-borne. *Myzus persicae, Macrosiphum euphorbiae* and *Neomyzus circumflexus* are vectors

Potato virus M (PVM) = M mosaic

Particle is flexuous or rods, normal length 650 μm and diameter 12 – 13 μm. PVM has been known by disease names as potato leaf rolling mosaic, paraclinkle and interveinal mosaic. The economic significance of PVM is uncertain. Infected plants appear mild mosaic, but severe symptoms are characterized by a twisting of the leaflet tip, some rolling of the top leaves, and sometimes cause veinal necrosis under the leaves. Infected plants are masked at higher atmosphenic temperature (about 24°C). PVM can be transmitted by sap and aphids Spread in the field is probably mainly by aphid. It is stylet-borne. Vecter are *Myzus persicae, Aphis nasturtii, A. frangulae* and *Macrosiphum euphorbiae.*

Potato aucuba mosaic virus (PAMV) = aucuba mosaic

Particle is flexuous, normal length 580 μm and diameter 11 – 12 μm. Infected plants appear clear yellow fleking on the middle or lower leaves of certain varieties PAMV is transmitted by sap, but this virus is transmitted by *Myzus persical* only when the infective plant contains both PAMV and PVA or PVY. PAMV may also transmitted by contact in the field.

Alfalfa mosaic virus (AMV) = calico

Potato calico disease caused by certain strains of AMV does not outbreak as many other virus, although AMV is known in worldwide. Particle is rod, range in length from 25 mm to 60 mm. Infected plant appear yellow-like mottle those of PAMV, but they are much larger and sometimes a complete leaflet may show the yellow color. AMV is transmissible by sap, but field transmission is by aphid. *Myzus persical, Macrosiphum eupharbiae* and *Aulacorthum pisum* are vectors, it is stylet-borne.

Cucumber mosaic virus

CMV is rarely found in potatoes. Infected plant manifests yellow leaves.

C Virus transmitted by other insects

Tomato spoted wilt virus (TomSWV)

Particle is spherical, about 70 – 90 μm in diameter. Infested plants appear necrotic spots or streaks on the stems and leaves. This virus transmitted by *Thrips* spp.

Andean potato latent virus

This virus practically manifests no symptom in potato.

D. Soil-borne virus

Tobacco rattle virus (TRV) = stem mottle

Particle is rods, ranges in length 180 μm and 75 μm. Infected plant manifests yellowish mottle on the leaves, also the mottle appear on the stems. TRV is transmitted by nematodes of the genus *Trichodorus* spp , it is persistent transmission.

Tomato black ring virus (TomBRV)

Particle is spherical 30 μm wide. Infested plant appears necrotic spots and rings on the leaves. TomBRV is transmitted by nematodes of the genus *Longidorus* spp., it is persistent transmission.

Potato mop top virus (PMTV) = mop top

Particle is rods 300 μm long and 15 μm wide Infected plants appear mop top, aucuba and chlorotic chevrons on the potatoes. PMTV is transmitted by potato powdery scab fungus, *Spongospora* sabterranea.

Tobacco necrosis virus (TNV)

Particle is spherical, about 26 – 30 mm in diameter. Infected plant appears dark-brown lesion on the tuber. TNV is transmitted by *Olpidium brassicae.*

E. Virus transmitted by leafhoppers

Potato yellow dwarf virus (PYDV) = yellow dwarf

Particle is bacilliform 380 μm long and 75 μm wide Infected plant appears yellowing and necrosis on the apical leaves. Symptom of tubers manifests internecrotic spots, malformation and cracking.

This virus occurs in U.S.A. and Canada PYDV is transmitted by leafhopper. Vectors are *Aceratagallia sanguinolenta, Agallia quadripunctata* and *A. constricta* PYDV is circulative and multiply in their vectors.

Mycoplasma-like organisms

This pathogen occurs potato diseases which are know as purple top wilt and witches' bloom. Shape is polymorphic, size in 80 – 800 μm Mycoplasma-like organisms are transmitted by leafhopper, *Scleroracus flavopictus.* They are circulated and multiply in teir vector.

2 Bacterial Diseases

Ring rot (*Corynebacterium sepedonicum*)

The bacterium is a gram possitive, short rods, 0.5 – 1.2 x 0.3 – 0.6 μm. The grams' stain is commonly used as a test in seed certification of this pathogen. This bacterium do not overwinter in the soil itself. It is mainly spread by infected seed tubers and by cutting knife. Symptom of haulms manifests a slight wilting of the leaves, then the leaves become pale-green, mottled, and chlorotic, then they develop a marginal necrosis and finally die. Symptom of tuber manifests a yellowish, cheesy rot of the vascular tissues, then shows a breakdown of the vascular ring.

Black leg (*Erwinia carotovora* var. *atroseptica* or *E. carotovora* var. *carotovora*)

The bacteria are gram negative, short rods, 0.6 – 0 8 x 1.5 – 2.5 μm They are mainly spread by infected tubers, and by cutting knife. Infected seed pieces occur to seed decay. They also affect the stems or tubers. Haulms of infected plant appear yellowing, slightly eilt and eventually die. Infected stem manifests black color, this is disease name. Infected tubers manifest internecrotic mottle in side of the stolon.

Bacterial wilt (*Pseudomonus solanacearum*)

This disease has a wide hostrange, including not only potato but tomato, tobacco and other Solanaceae. Regional occurrence is recognized in the southern and warm regions. Infected plant manifests a wilting of the leaves during the daylight with recovery at night, but eventually in plants fail to recover, and then die. This pathogen is soil-borne.

Bacterial soft rot (*Erwinia carotovora* var. *carotovora*)

This disease outbreaks under humid and warm conditions, it is presents in the soil. Infected stem manifests a brown color, leaves appear yellowing, and they appear wilting. Infected tubers occur soft rot.

Common scab (Streptomyces scabies)

This disease is only affects tubers. It manifests scab on the surface of the ones.

3. Fungus Diseases

Late blight (*Phytophthora infestance*)

This disease is one of the most important diseases of potato. Infected leaves have a water-soaked appearance at first, the leaves turn brown color and dry up. In severe case, infected plants may be killed. Late blight can be controlled by spraying of fungicides. Potato tuber is also affected, late blight rot occurs by this pathogen.

Black scurf (*Rhizoctonia solani*)

This disease is affected with young sprouts or shoots, and appear a brown lesions on the ones. Infected mature plants appear brown canker with longitudinal crater or crack on the stem. Top of the upper leaves often roll up and brown or black hard bodied outbreaks on the surface of tuber.

Early blight (*Altanaria solani*)
Verticillium wilt (*Verticillium albo-atrum*)
Powdery scab (*Spongospora subterranea*)
Wart (*Synchytorium endobioticum*)
Anthracnose (*Colletotrichum atramentarium*)
Silver scurf (*Spondylocladium atrovirence*)

Selerotical rot (*Sclerotinia sclerotiorum*)
Dry rot (*Fusarium solani*, *Fusarium* spp.)
Grey mold (Botrytis cinerea)
Violet rot (Helicobasidium mompa)

4. Potato Nematodes

Potato cystnematode (= golden nematode, *Heterodera rostochiensis*)
Potato rot nematode (*Ditylencus destructor*)
Virus vectors (*Trichodorus* spp.; *Longidorus* spp.)

5. Insect Pests

Potato tuber moth (*Phthorimaea opeculella*)
Colorado potato beetle (*Leptinotarsa decemlinata*)
Lady beetles (*Epilachna vibitioctopunktata; E vigintioctomaculata*)
Wire worms (*Agriotes fusciollis; Melanotus fortunei; Sclatosomus punctiollis*)
More cricket (*Gryllotalpa africana*)
Virus vectors
Leaf hoppers (*Scleroracus flavopictus, Aceratagallia sanguinotenta; A. constricta*)
Aphids (*Myzus persicae; M. ornatus; M ascalonicus; M certus, Aphis nasurtii; A. gossypii, Macrosiphum euphorbiae; Aulacorthum solani; Neomyzus circumflexus*)

III. CULTURE OF SEED POTATOES

1. Environmental Conditions

Favorable cultivation condition for seed potato is the same as the condition suitable to potato growth. However, because major purpose of seed potato cultivation is to control tuber-borne diseases. The cultivation of seed potato must be isolated from infected plants and vectors of the viruses. Desirable region to produce seed potato is high, cool region. A district with constant wind blowing during the potato growing season such as sea side is preferable. Another favorable condition for seed potato production is that a farm is surrounded by wind-break forest and is not planted with the plants of Solanaceae and Burseraceae or no planting of commercial potato in the surrounding areas.

2. Crop Rotation in Seed Farm

It is desirable that crop rotation is carried out in seed farm with an objective to maintain soil fertility, to control weed and disease and insect. The crop rotation should avoid the cultivation of Solanaceae plants which have common disease and insect as potato. Soil disease such as Verticillium wilt, black scurf, common scab or bacterial wilt and other soil-borne diseases are less troublesome when potatoes are grown in rotation with other crops. These diseases can be controlled by the ratation of one of the five years.

3. Soil Conditions

Suitable soil conditions in seed potato production are deep and well drained silt loam or sandy loam with slight acidity of pH 5.5 – 6.5 It is generally assumed that Black scurf easily outbreaks in acidic soil and Common knotty second growth or elongated tuber scab in alkali soil. As for the degree of soil moisture dry soil is preferable which invites suitable growth of tuber but over-dryness produces discontinuous growth, knotty second growth or elongated tuber. Therefore, irrigation is necessary.

4. Healthy Seed Tubers

Seed potato to be planted in seed farm are those which have been propagated systematically in that district. However, in case no such system exists healthy seed must be produced by roguing and by preventing the infection of disease in field Methods to produce healthy seed potato in planting and harvesting is know as tuber indexing and hill indexing.

a) Tuber indexing method

Indexing is on individual tuber and the tubers are numbered, and small pieces including a single eye are removed by cutting from parent tuber. Then the pieces are planted for observation or testing, usually in greenhouse. When diseased plants are found, all tubers with marked number are discarded, so that next culture is only planted healthy seed tubers.

b) Hill indexing method

Indexing is on individual hill, and a single test tuber is taken from each hill. Testing or observation are carried out similar tuber indexing.

5. Planting

Before planting seed tubers are selected by the shape and disease or insect damages, and are sterilized by dipping into fungicide solution. After selection and dipping seed tuber is placed in glasshouse or warm room for sprouting. Suitable number of sprouts is one or two. Tuber is cut up to increase the number of seed piece Cutting knife sterilized by $HgCl_2$ is used to prevent tuber-borne bacterial disease such as bacterial ring rot. The weight of 30 g for seed piece about normal productivity. It is desirable that cutting tubers are planted by tuber unit Tuber unit planting is planted by place in lines the cut piece in a tuber unit. This planting has an advantage as follows: some plant in a tuber unit may not manifest the stem symptom, and it can be easily roguing, and to grouped hills are less source of infection by diseases.

Fertilizers for the seed potato must have sufficient supply of minerals. Excessive nitrogen is dangerous for delay to growth and mature of tuber. Phosphorus and potassium must have sufficient supply for developed symptoms of virus diseases and produced high quality tubers. Average of planting hills is about 50,000 plants per ha., row are 65 – 75 cm apart. In planting, granulated systemic insecticides are applied to control aphid in soil together with fertilizers.

6. Field Managements

Seed field is usually managed by the same method as for the production of commercial stocks. However, special growers of seed potato must be careful to produce tuber-borne disease-free seeds and varietal purity. Main managements in seed field are roguing of virus diseased plants or unsuitable hills and preventing from infection of viruses.

A Roguing of diseased plants

Virus diseased plants are normally rogued before vectors arrive. The roguing should start as soon as the plants are 15 ~ 20 cm high, and thereafter once a each week. Diseased plants are carefully dug up, the whole plant, including mother tuber and any new tubers, is placed in a vinyl bag to prevent any aphids escaping. They must be put out of the fields and quickly disposed by burning or destruction. Roguing mainly removes tuber-borne diseases, at the same time, it is removed other diseases or insect damages and different varieties.

B. Detection of viruses

Symptom-manifested plants are removed by roguer. However, sometimes, because of weather conditions or mild strains of virus, not all plant manifest symptom. In such a case, the virus must be detected by using inoculation or indication host test[c], serological test[d], electron microscope test[e], and histrogical test[f]. Bacterial ring rot is also used grams' stain test.

C) Indicator host (inoculation) test

Two types of test are commonly used: that which develops systemic symptoms by rubbing and that which develops local lesions in inoculated leaves. Seed potato certification is generally used local lesion hosts, these plants appear local necrotic spots or rings on the inoculated leaves. Combinations of virus and hosts show as following. PVX (PVS, PVM) and *Gomphrena globosa*, PVY, PVA (PVX) and *Solanum demissum* A-6 (*S. demissum* x *S. tuberosum* "S. "Aquila"), PVM and *Phaseolus vulgalis*, PVS and *Chenopodium quinoa*, PAMV and *capicicum annuun*, and AMV and *Vigna sinensis*. Inoculation to indicator hosts is carried out rubbing usually carboroundum (300 ~ 600 mesh) mixed with expressed juices of sample leaves.

D) Serological test

This test is based on reactions between antigens and antibodies. When injected into the body of a rabbits, antigens (purified viruses) cause the formation of specific antibodies, which are protein of the -globlin type. In vitro, out side the rabbit body, antibodies can react by flocculating with their corresponding virus antigens. Producing antibodies in blood is called antiserum. In seed potato cerfication is mainly used agglutination test. These tests are based on serological reactions on the surface of large particles and on the resulting clumping or agglutination of those particles. The most easily test is used as slide agglutination in this test, one or two drops of diluted antiserum are mixed on a glass slide with one or two drops of crude juice from the plants to be tested. This test has been used detection to PVX and

PVS. Other tests use special methods in laboratory, because the testing of the large number of plants is impossible.

E) Electron microscope test

The electron microscope gives much information on size, shape and structure of the particles. In seed potato certification, this test is observed by the direct negative staining method. Tested leaf pieces are cut several times in a droplet of 1 – 2 per cent phosphotungstic acid solution (pH 7) on glass slide, and its ride on colodion-coated copper grid dried and the specimen is ready for examination with the electron microscope. This test is mainly used detection of elongated viruses such as PVX, PVA, PVY, PVS, PVM and PAMV, but spherical viruses such as PLRV cannot be detected easily.

F) Histological test

PLRV causes phloem necrosis in injected potato stems, it is stained by phloroglucinol and HCl, but this method is not common used. For practical diagnosis of PLRV in seed potatoes, detection of excessive callose in stems and tubers has been introduced in European countries. This method is called the Igel-lange test. Callose stains are used 1 per cent aqueous solution of resorcin bule, which turn callose deep blue.

C. Prevention of infection

Aphids are the most important vectors in potato. For aphid controls, at the planting time granulated systematic insecticides should be applied in the soil. For example, the application of 5% granules of ethyl-thiometon at a rate of 1 g. per a hill give good result in reducing the spread of virus diseases. Effective periods of these insecticides are about 60 days. Thereafter, liquid insecticides are sprayed several times during the growing season.

Late blight is common in potato diseases, and susceptible varieties are sprayed every week in accordance with the weather. Zineb or manneb fungicides are used for spraying.

To prevent the spreading of virus by aphids or to prevent late blight, haulms are destroyed in late growing season. Haulms destruction can be carried out various ways, in which haulm pulling, by burning with a flame thrower, and by spreading herbicides of contact type are used.

7. Harvesting

Harvest is usually 2 - 3 weeks after destroying haulms when tuber skin are fully firm and the connection between tubers and stems is sufficiently loose. Seed potatoes are harvested by digger and picked up by hand. In such a way the wound of the tuber can be reduced. Harvested tubers are stored in well ventilated barn or cool warehouse for 2 - 3 weeks. Pre-storage treatments are carried out to weight of put down with physiological reaction (respiration) in the tuber.

Tubers after the pre-storing treatments are selected by the size ranges, irregular shaped, insects or diseases damages, green that is unsuitable tubers are picked out. Selected tubers are sent to growers or to ventilated storage house.

IV. SEED POTATO PRODUCTION PLAN

Potato is a crop which has propagation ratio about 8 - 10 times less than cereal crops. Because thereof, no rapid propagation of seed potato is possible Production of seed potatoes are systematized, at first, basic plant which has high quality is produced, then it is regularly propagated to foundation seeds.

This chapter describes seed potato producing schemes in some countries.

1. The Netherland

The Netherland General Inspection Service (NAK) was established in 1932 under the government jurisdiction to certify seed potato. Regulation for inspection have to be approved by Minister of Agriculture. Directive on inspection and certification are issued by the seed potato control office in Wageningen. The directives are strictively and effectively enforced by 8 regional inspection services.

Seed potato's clonal propagation scheme is as shown hereunder in Fig. 1. Clonal selection is selection of clones meeting varietal characteristics and free from tuber-borne disease. Clones are propagated from a single plant (basic plants), tubers from this plant are kept together as seed for first-year clone. This procedure is repeated five lines producing second-, third-, fourth- and fifth-year clones. The tubers are always stored and propagated separately from other clones. Clones are selected on farms approved by the NAK, and it keeps close control on donal stocks during the selection. Tubers are checked each season. The crop is inspected in the field and tested for viruses in the laboratory during the growth. Control and regional fields check the clone for varietal characteristics. If clones are certified, third, fourth and fifth year stocks fall into grade S (super). Grade SE (super elite) is produced by using grade S, and seed potatoes are regularly propagated grade E, A, B and C Certified seeds are grade A, B and C.

2. U.S.A. and Canada

In Canada seed potato certification is directed by the central government in Canada. In the United States Government agencies provide regulations on the production of certified seed stock, either by the Department of Agriculture of respective State, State college of agriculture or State-designated seed association. Each of these agencies is responsible for seed standard and seed inspection with respect to free-from-disease and varietal purity. Scheme of seed potato is to propagate basic seeds which are mother clone free from virus and ring rot. Basic

seeds are regularly propagated elite I, II and III.

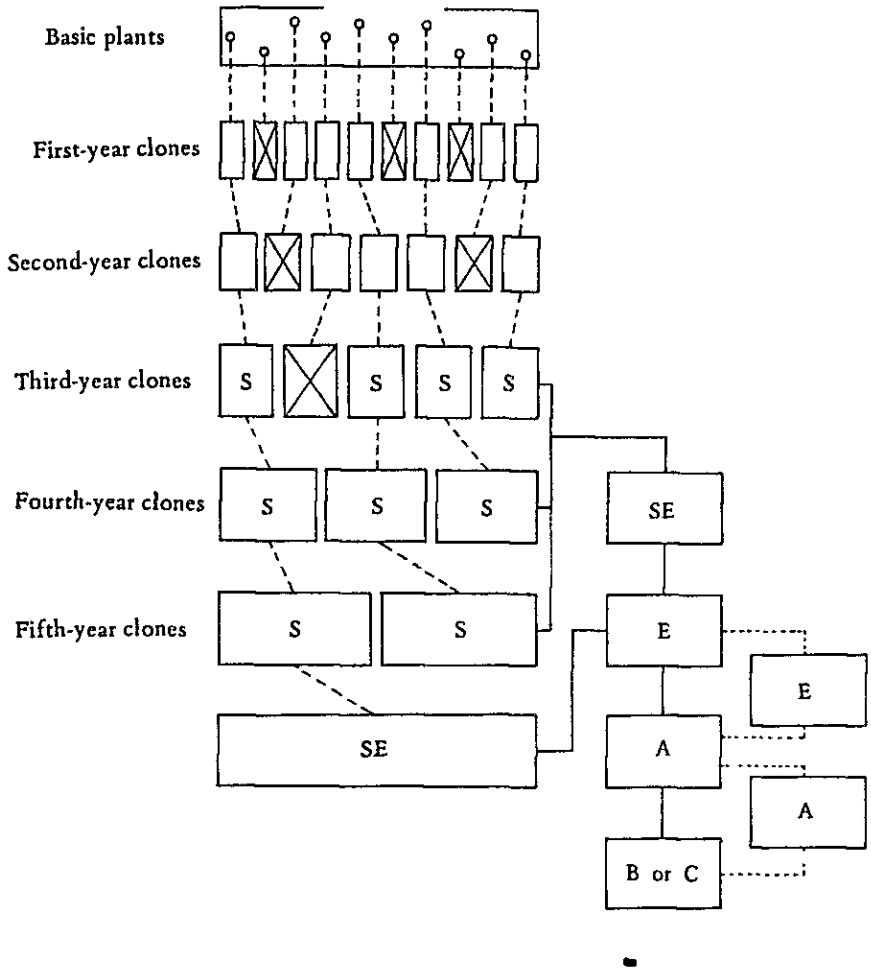
Seeds produced under elite III are foundation stock seeds. And certified seeds are produced by using this foundation stock seeds.

3. Japan

Japan's seed potato producing scheme is as shown in Fig. 2. First the foundation stock seed potato is produced by the Foundation Stock Seed Farm of the Ministry of Agriculture, Forestry and Fisheries. There are such Farms throughout the country from cold region of Hokkaido, the northernmost island to warm Kyushu, the southernmost island. The foundation stock seeds are transferred to stock seed farm of respective prefecture operated by prefectural government then to designated seed grower from which the seeds are marketed to farmer.

Foundation stock seeds are produced by means of meristem tip culture regularly propagated in greenhouse or net house. Then it goes through three stages of culture. The foundation stock seeds are the products of third culture.

All certified seed produced by designated seed growers are strictly inspected by the Plant Protection Service of the Ministry of Agriculture, Forestry and Fisheries. It can be said that the quality of seed potato is guaranteed by the government.



☒ : Rejected at field inspection, serological test, judgement on type or tuber indexing.

——— : Crop is passed to the grower.

---------- : Crop is replanted by the grower.

S, SE, E, A, B & C : Quality grades of seed potatoes.

Fig. 1. Scheme of Clonal Propagation of Seed Potatoes

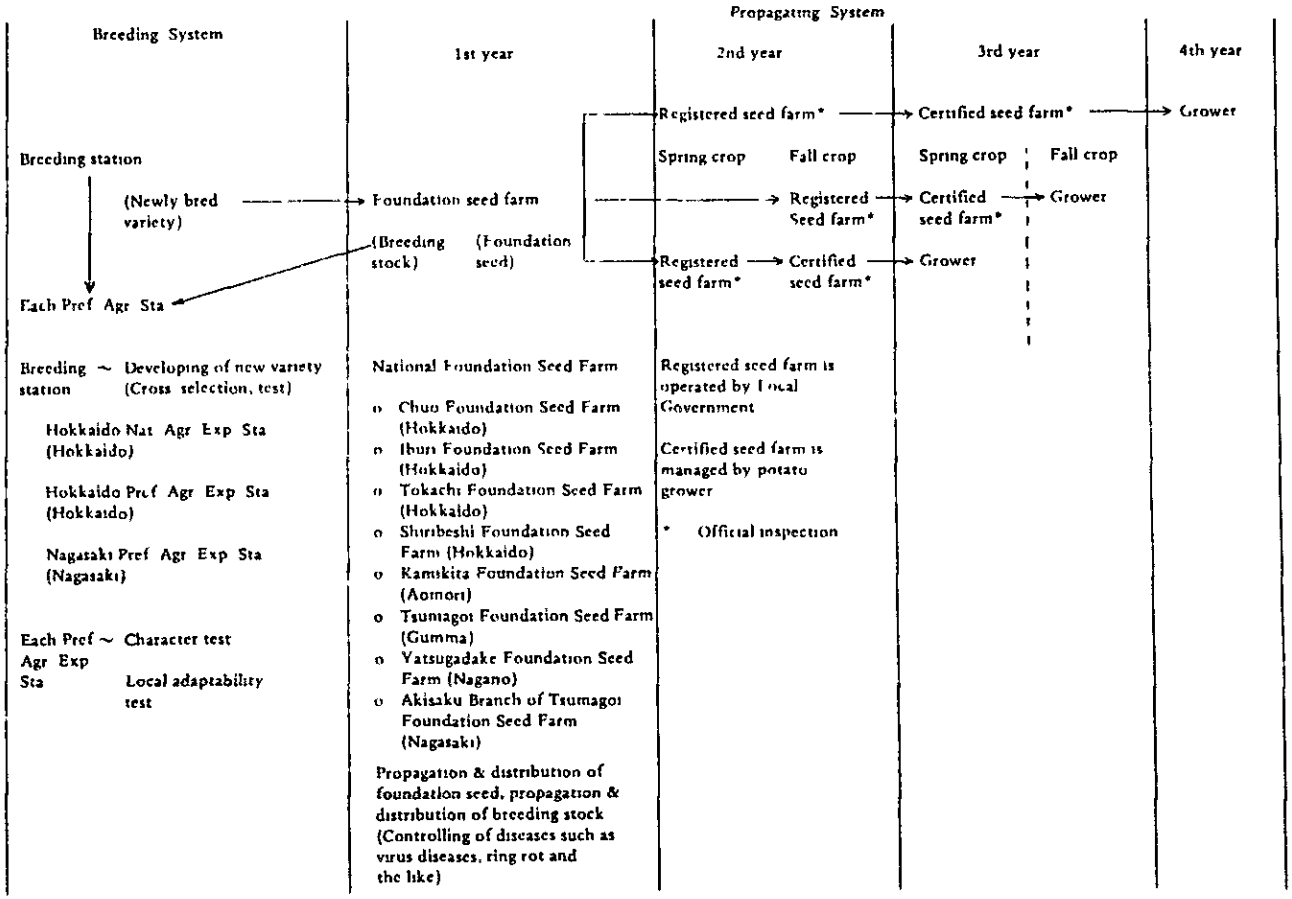


Fig. 2. The Scheme of Potato Breeding Works and Seed Potato Producing Works