THE PHYSIOLOGICAL DEGENERATION OF POTATO SEED TUBERS AND ITS CONTROL[1]

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1. INTRODUCTION

The function of seed tubers is of vital importance in the production of potato tubers. Although emphasis is laid on the use of good seed tubers, their superiority is only in evidence during the first crop season and never extends to the following seasons.

Some consider virus diseases, climatic and cultural factors, etc. to be among the causes of degeneration (SIVORI, 1951; TIZIO, 1951; TIZIO *et al.* 1954; WENT, 1959; THOMPSON, 1939). The author has previously shown that the physiological condition of seed tubers is also an influential factor (KAWAKAMI, 1936, 1950, 1952).

Having regard to the physiological aspects involved, it may be inferred that degeneration of this type is prevalent throughout the world.

2. PHYSIOLOGICAL DEGENERATION

After starting independent life, each tuber exhibits its own characteristic growth according to the stage in the life cycle. It depends, however, on the specific stage of its life when the seed tuber exhibits optimum growth. The stage of tuber life is indicated by the number of months. According to this classification, when seed tubers are planted at the proper age they perform the highest function. When the seed tubers are planted before or after the proper age their function is reduced accordingly. The reduction in yield caused by the unsuitable age of seed tubers is termed "physiological degeneration" (KAWAKAMI, 1936).

According to the physiological theory, the proper age of the seed tuber is about 4–6 months. Physiological degeneration occurs in areas in which it is hardly possible to produce home-grown seeds of the proper age. Two types may be distinguished, viz. juvenile degeneration and senile degeneration. In the former case dormancy results in unsatisfactory sprouting. In the latter case a character appears that exhibits the growth degeneration due to earliness and decrepitude. The clearest cases of physiological degeneration appear in spring and early summer crops.

Spring-, summer- and autumn-grown seed tubers are available for planting the spring crop in spring crop areas, the only homegrown seeds being the spring-grown ones. Since the latter are too old (9 months) summer- or autumn-grown seeds have

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to be introduced from summer or autumn crop areas respectively in order to obtain good seeds of the proper age. TABLE 1 shows the age in months of available seed tubers for each type of crop season. The numerals denote the proper age for planting. This was standardized with *Irish Cobbler*. The proper age in months is not only modified by the crop seasons and cultural practices or aims, even within the same variety, but also by the different rest period and maturity.

TABLE 1. Age of seed tubers available for each type of crop season

Crop season – *Anbauzeit – saison de culture*	Seed available for each type of crop season – *Saatgut, erhältlich für jede Anbauzeit – des plants disponibles pour saison de culture*					
	Early spring-grown[1]	Spring-grown[2]	Early summer-grown[1]	Summer-grown[2]	Autumn-grown[2]	Winter-grown[2]
Early winter[3]	–	5	3	2	–	–
Winter[1]	–	–	4	3	–	–
Early spring[3]	9*	8	6	4	2	–
Spring[1]	–	9*	8	6	3	–
Early summer[3]	–	–	9*	7	4	–
Summer[1]	–	–	–	8*	5	–
Early autumn[3]	–	–	–	–	–	3
Autumn[1]	3*	2*	–	–	–	4

Note – *Anmerkung – nota*
Numerals denote the proper age for planting (months). – *Die Ziffern geben das geeignete Alter für das Auspflanzen an (Monate).* – *les chiffres indiquent l'âge exactement apte à la plantation (mois).*

* Home-grown seed – *Saatgut aus Eigenbau – plants de culture particulière.*
[1] *Im Vorfrühjahr (Frühsommer) gezogen – cultivés au début du printemps (de l'été).*
[2] *Im Frühjahr (Sommer, Herbst, Winter) gezogen – cultivés au printemps (en été, en automne, en hiver).*
[3] *Vorwinter (Vorfrühjahr, Frühsommer, Frühherbst) – au début de l'hiver (du printemps, de l'été, de l'automne).*
[4] *Winter (Frühjahr, Sommer, Herbst) – l'hiver (le printemps, l'été, l'automne).*

TABELLE 1. *Alter des für jede Anbauzeit zur Verfügung stehenden Saatgutes*
TABLEAU 1. *L'âge des plants disponibles pour chaque saison de culture*

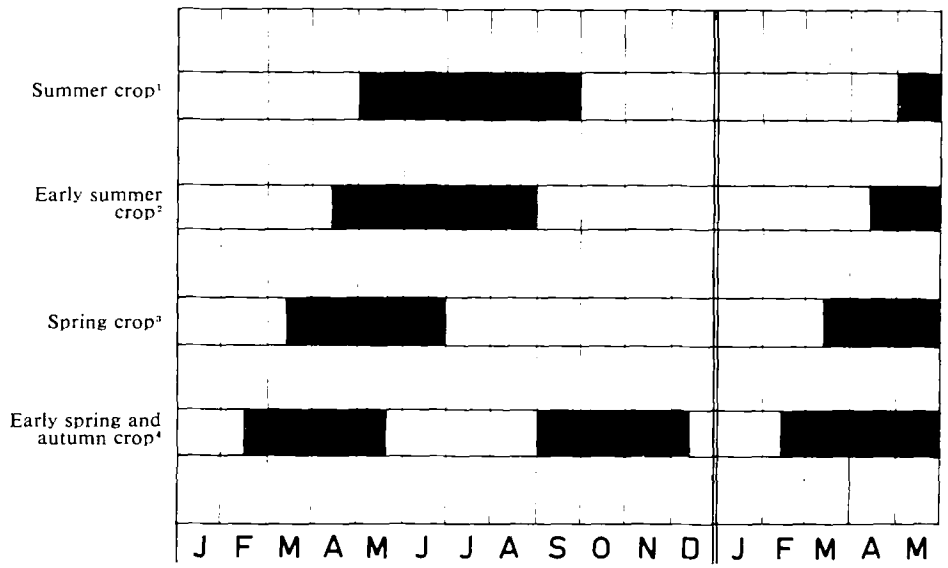
3. SENILE DEGENERATION

When only one crop is cultivated a year, as in areas producing an early summer crop or those producing a spring crop, the seed tubers are stored for long periods. In areas producing an early summer crop the period extends from August to April and from June to February in areas producing a spring crop. In both areas the period is 9 months (see FIG. 1).

For example, in areas with an early summer crop autumn-grown seeds (0) sent from warm areas are lifted in December and awaken from dormancy in February, and in April (the planting time) the seeds grow 1,3 sprouts (FIG. 2 and 3). When these are planted in April and harvested in August it is found that the potatoes produced (H1) are lifted 5 months earlier than the original seeds (0) (FIG. 4).

During the life of the plant the progress made is shown by the number of stems (KAWAKAMI, 1936, 1952; MADEC, 1958; KRIJTHE, 1958; PERENNEC and MADEC,

FIG. 1. Distribution of types of potato crop seasons in the principal producing areas of Japan



[1] *Sommeranbau – culture d'été.*
[2] *Früher Sommeranbau – culture d'été précoce.*
[3] *Frühjahrsanbau – culture de printemps.*
[4] *Früher Frühjahrs- und Herbstanbau – culture de printemps précoce et culture d'automne.*

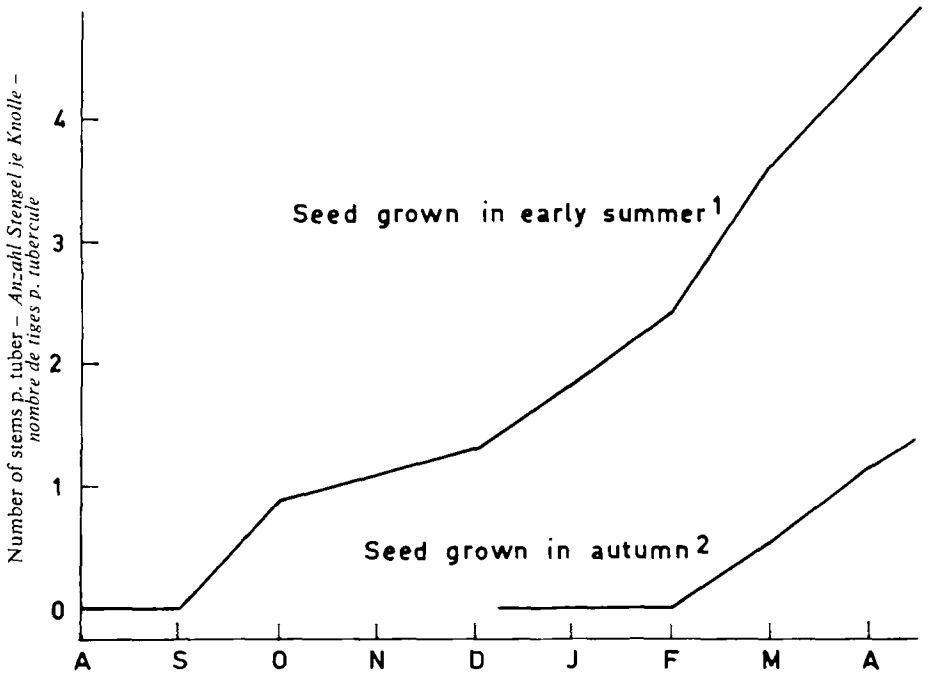
ABB. 1. *Streuung der verschiedenen Anbauzeiten in den Hauptanbaugebieten in Japan*
FIG. 1. *Distribution des différentes saisons de culture de pommes de terre dans les principales régions de culture du Japon*

1960). In the second-year planting period home-grown seeds (H1) produced more stems than original seeds (0) (FIG. 2 and 3). The long storage period affects productivity and shows a 37 % reduction (KAWAKAMI, 1950). To this is added the effect of the increased number of stems per hill, and under the usual conditions of cultivation productivity falls 60 %. The unit of potato productivity is primarily a stem, and since the number of tubers produced per stem is almost constant, tuber development is controlled and tuber-size is reduced. The relationship between seeds grown in early summer and autumn in areas of early summer crops is also in agreement with the relationship between spring-grown seeds and summer-grown seeds in spring crop areas.

4. JUVENILE DEGENERATION

For spring planting in double crop (early spring and autumn) areas, summer-grown seeds are introduced from summer crop areas. In this case the spring seeds of home-grown (H1) plants are used for autumn planting and home-grown seeds (H2) for spring planting in the succeeding year and there is juvenile degeneration. In summer

FIG. 2. Seed grown in early summer showing an increased number of sprouts compared with seed grown in autumn. Both types of seed being planted for early summer crop



[1] *Im Frühsommer gezogene Saatknollen – plants cultivés au début de l'été.*
[2] *Im Herbst gezogene Saatknollen – plants cultivés en automne.*

ABB. 2. *Das im Frühsommer gezogene Saatgut hat eine grössere Anzahl Triebe wie das im Herbst gezogene. Beide Saatguttypen werden für den frühen Sommeranbau benutzt*

FIG. 2. *Plants cultivés au début d'été montrent un plus grand nombre de pousses en comparaison des plants cultivés en automne. Les deux types de plants sont utilisés comme semence dans la culture d'été précoce*

crop regions the summer-grown seeds (0) are cultivated on the May-planting and September-harvesting system, whereas in double crop areas seeds are planted in September and harvested in December. For this reason autumn-grown seeds are lifted 4 months later than those grown in summer. Consequently the dormant period is also prolonged and in March, the time for planting spring crops, sprouting is still retarded to a certain extent.

Except in certain areas and certain varieties juvenile degeneration is inevitable when spring-grown seeds are used for autumn crops.

5. DISTRIBUTION OF PHYSIOLOGICAL DEGENERATION

TABLE 1 shows that suitable seed tubers can only be home-grown for summer-grown seeds in summer crop areas and early spring-grown seeds in double crop areas.

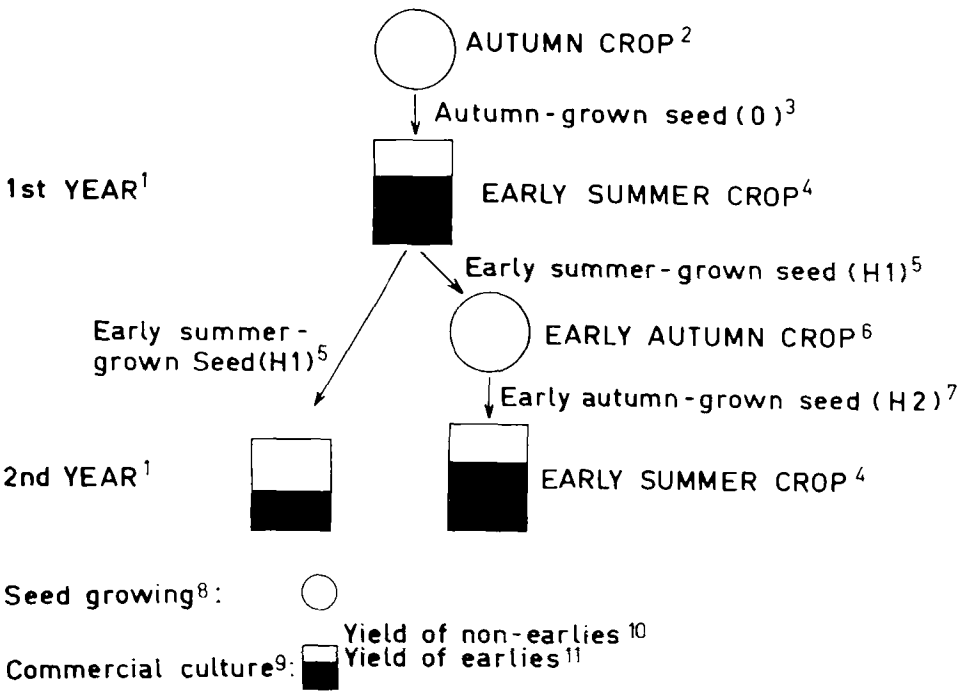
FIG. 3. *Effect of seed-tuber age on sprouting and growth in the early summer crop*

ABB. 3. *Einfluss des Saatgutalters auf Keimung und Wachstum des frühen Sommeranbaus*
FIG. 3. *L'effet de l'âge des plants sur la germination et la croissance de la culture d'été précoce*

Moreover in TABLE 2, there is scarcely any example of the high productivity of home-grown seeds. The total yield from summer-grown seeds is high in summer crops but there are usually less earlies than those obtained from autumn-grown seeds. The relationship between month and productivity is not absolute but relative. Thus unlike spring crops of Saga, autumn-grown seeds sometimes give no yields when harvested early (TABLE 2). In the normal harvest the yields can be increased by as much as 75 % compared to summer-grown seeds.

In short, this indicates that physiological degeneration occurs in all areas. It may be overcome by cultivating during different seasons and employing seed tubers of different ages.

FIG. 4. Diagram showing degeneration control in early summer crop areas



[1] *Erstes (zweites) Jahr – 1re (2e) année.*
[2] *Herbstanbau – culture d'automne.*
[3] *Im Herbst gezogenes Saatgut – plants cultivés en automne.*
[4] *Früher Sommeranbau – culture d'été précoce.*
[5] *Im Frühsommer gezogenes Saatgut – plants cultivés au début de l'été.*
[6] *Früher Herbstanbau – culture d'automne précoce.*
[7] *Im Frühherbst gezogenes Saatgut – plants cultivés au début de l'automne.*
[8] *Saatgutgewinnung – culture de plants.*
[9] *Handelsanbau – culture commerciale.*
[10] *Ertrag nicht-früher Kartoffeln – rendement de pommes de terre tardives.*
[11] *Ertrag von Frühkartoffeln (Erstlinge) – rendement de primeurs.*

ABB. 4. *Schematische Darstellung der Abbaubekämpfung in Gebieten mit frühem Sommeranbau*
FIG. 4. *Représentation schématique montrant la lutte contre la dégénération dans les régions à cultures d'été précoces*

6. CONTROL OF PHYSIOLOGICAL DEGENERATION

The degeneration of potato seed tubers is not due to production conditions but to the time which elapses between lifting and planting. Some researchers consider that the functions of seed tubers are already determined during the production period. For instance, THOMPSON (1939) stated that the reason why in all areas of the U.S.A. use is made of potatoes grown in the north is due to the fact that further south the temperature during the growing period is so high that potatoes of degenerated vitality are produced. But even in the south there is no devitalization of potatoes planted in

TABLE 2. The effect of age (in months) on the productivity of potato seed tubers

Author – *Verfasser – auteur*	Location – *Ort – indication du lieu*	Crop season tested – *beobachtete Anbauzeit – saison de culture observée*	Seed – *Saatgut – plants*		Relative productivity *Relative Produktivität Productivité relative*	
			Age *Alter Age*	Origin *Herkunft Origine*	Total	Primes *Erstlinge Primeurs*
Kawakami (Japan)	Ehime 1959	winter	7	early spring grown*	65	41
			3	summer grown (Nagano)	100	100
Kimbrough (U.S.A.)	Louisiana 1936–38	spring	9	spring grown*	65	–
			5	summer grown (Northern)	100	–
			3	autumn grown*	66	–
Kasai (Japan)	Saga 1938–39	spring**	(7)	spring grown*	62	–
			(4)	summer grown (Hokkaido)	100	–
			(2)	autumn grown*	0	–
Kasai (Japan)	Saga 1938–39	spring	(7)	spring grown*	50	–
			(4)	summer grown (Hokkaido)	100	–
			(2)	autumn grown	75	–
Kawakami (Japan)	Iwate 1958	early summer	9	early summer grown*	75	–
			4	autumn grown (Okayama)	100	–
Takasaki (Korea)	Suwon 1926	early summer	(9)	early summer grown*	62	–
			(4)	autumn grown (Nagasaki)	100	–
Martin (U.S.A.)	New Jersey 1925	early summer	(9)	early summer grown*	?	–
			(5)	summer grown (Maine)	100	–
Rosa (U.S.A.)	Missouri 1919	early summer	(9)	early summer*	98	77
			(5)	summer grown (Northern)	100	100
Kawakami (Japan)	Nagano 1958	summer	8	summer grown*	105	78
			5	autumn grown (Okayama)	100	100
Kawakami (Japan)	Okayama 1959	autumn	5	winter grown (Ehime)	100	100
			3	early spring grown*	57	21

* Home-grown seed – *Saatgut aus Eigenbau – plants de culture particulière.*
** Early harvest – *Frühernte – récolte précoce.*
( ) Presumed age – *geschätztes Alter – âge estimé.*

TABELLE 2. *Einfluss des Alters (in Monaten) auf die Produktivität vom Kartoffelsaatgut*
TABLEAU 2. *L'effet de l'âge (en mois) sur la productivité de plants de pommes de terre*

the latter part of summer for the second crops, this being due to low temperature during the growing period.

However, this is only valid for March-April planting. Taking the cultivation of potatoes in a broad sense, this theory does not necessarily apply to early autumn

crops or winter crops. According to WENT (1959), potatoes grown at a low temperature are rich in tuber-forming substances. This influence ranges over several generations of tubers. This has not yet been shown to be related to the advance in age in months. Although potatoes may be produced at a low temperature, when the storage period is long seed tubers are not always considered superior to those of the short storage period grown at a high temperature.

The physiological degeneration of seed tubers can be prevented by producing seed tubers of the proper age. As regards senile degeneration, a seed has been grown by autumn cultivation that reduces the age in months (FIG. 4).

KAWAKAMI (1936) in Iwate-Ken, TAKEDA (1934) in Korea, HATTA and TAKASAKI in Korea, ROSA (1922) in Missouri, have been successful in this respect. There are examples which show that seed tubers may be effectively produced by late planting. In Missouri MARTIN (1925) succeeded in obtaining seed of a suitable age by August planting. In Germany, BERKNER and HECKER (1935), BERKNER (1935), and HEY (1938) obtained productive seed tubers by July planting. In England, however, BROADBENT (1957) failed to obtain productive seed tubers by August planting. This was probably due to conditions which led to juvenile degeneration.

When conditions make it impossible for the grower to have a suitable crop season for the production of seed tubers, seeds have to be introduced from another area. The standard to be selected primarily depends on the type of crop season. From the point of view of seed production one should select the type of crop season that gives the best results and the products should be sent to areas in which this type is used.

Finally, from the point of view of seed-tuber physiology it is desirable that seed tubers of the optimum age should be grown over wide areas during the suitable type of crop season. Crop season types should also be investigated on the basis of the physiology of seed tubers and the supply and demand system should be worked out. The rationalization of potato production will then receive greater attention.

SUMMARY

1. After starting independent life, the potato tuber exhibits its own growth characteristics according to each stage in the life cycle. The term "proper age" denotes the stage at which the seed tuber performs the highest function. When the seed tuber is planted before or after the proper age degeneration is proportionate to the time interval. This is known as physiological degeneration.

2. Degeneration that occurs before the proper age is reached, is termed juvenile degeneration and senile degeneration that occurring after the proper age (FIGS. 2 and 3).

3. The age is calculated in months. Taking into consideration varieties, cultural practices, type of crop season, etc. (TABLE 1), the proper age is considered to be 4–6 months.

4. In most areas the time of year selected for potato growing often proves unfavourable for the use of seed tubers at the proper age (FIG. 1 and TABLE 2). This is because physiological degeneration is extremely widely distributed and the loss is also large, and special measures have to be taken to obtain seed tubers of the proper age.

5. In order to control physiological degeneration it is advisable to grow seed tubers that can be lifted 4–6 months before planting, or the seed tubers should be obtained from areas in which seed is grown during the appropriate crop season (FIG. 4).

ZUSAMMENFASSUNG

DIE PHYSIOLOGISCHE DEGENERATION VON SAATKARTOFFELN UND IHRE BEKÄMPFUNG

1. Nachdem sie ihr selbständiges Leben begonnen hat, zeigt die Kartoffelknolle ihre eigene Wachstumscharakteristik entsprechend den einzelnen Stadien des Lebenszyklus. Die Bezeichnung "geeignetes Alter" ("proper age") bedeutet das Stadium, in welchem die Saatknolle am leistungsfähigsten ist. Wird die Knolle vor oder nach dem geeigneten Alter ausgepflanzt, so tritt Degeneration entsprechend der Zeitdifferenz ein. Dies ist die physiologische Degeneration.
2. Die vor dem geeigneten Alter eintretende Degeneration ist die "juvenile Degeneration"; die nach diesem Alter eintretende die "senile Degeneration" (ABB. 2 und 3).
3. Das Alter wird in Monaten ausgedrückt. Als geeignetes Alter wird normalerweise 4 bis 6 Monate angenommen; je nach Sorte, Anbauweise, Anbauzeit usw. (TABELLE 1).
4. In den meisten Gegenden erweist sich die für den Kartoffelbau gegebene Jahreszeit häufig als ungünstig für die Verwendung von Saatkartoffeln im geeigneten Alter (FIG. 1 und TABELLE 2). Die physiologische Degeneration erstreckt sich dadurch sehr weit und der Verlust ist ebenfalls beträchtlich; es sind daher Vorkehrungen nötig, um Saatkartoffeln von geeignetem Alter zu erhalten.
5. Um der physiologischen Degeneration entgegenzuwirken, empfiehlt es sich daher, Saatkartoffeln zu züchten, die 4 bis 6 Monate vor dem Auspflanzen gerodet werden können, oder die Saatkartoffeln aus Gegenden zu beziehen, wo die Pflanzguterzeugung in der geeigneten Anbauzeit betrieben wird (FIG. 4).

RÉSUMÉ

DÉGÉNÉRESCENCE PHYSIOLOGIQUE DES PLANTS DE POMME DE TERRE ET LUTTE CONTRE CETTE DÉGÉNÉRESCENCE

1. Après avoir commencé son existence indépendante, le tubercule de pomme de terre présente ses propres caractéristiques de croissance correspondant à chaque phase du cycle vital. Le terme "âge approprié" ("proper age") désigne la phase où les fonctions du plant sont à leur maximum. Lorsque le tubercule de semence est planté avant ou après l'âge approprié, il se manifeste une dégénérescence correspondant à la différence avec l'âge approprié. C'est ce qu'on nomme la dégénérescence physiologique.
2. La dégénérescence provoquée par la plantation avant l'âge approprié se nomme "dégénérescence juvénile". Celle qui résulte de la plantation retardés s'appelle "dégénérescence sénile" (FIG. 2 et 3).
3. L'âge est exprimé en mois. On situe l'âge approprié à 4–6 mois, selon la variété, les techniques de culture, le type de saison de culture, etc. (TABLEAU 1).
4. Dans la plupart des régions, la saison de l'année consacrée à la culture de la pomme de terre se révèle défavorable à l'emploi de tubercules d'un âge approprié (FIG. 1 et TABLEAU 2). C'est pourquoi la dégénérescence physiologique est très répandue et les pertes sont également importantes. Il faut donc chercher à se procurer des plants de pomme de terre d'un âge approprié.
5. Pour la lutte contre la dégénérescence physiologique, il est recommandable de cultiver des plants de pomme de terre pouvant être arrachés 4 à 6 mois avant l'époque de la plantation ou de se procurer des plants provenant de régions où la culture des plants est effectuée dans la saison appropriée (FIG. 4).

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