Importance and Implications of the Physiological Age of Seed Materials of Tropical Root Crops

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Abstract

The harvested part of tuber crops is mostly used as seed material. Since yield depends highly on the quality of seed, the physiological age as a part of seed quality is an important factor. It can be determined before planting on the phenotype of the tuber or of the growing plant. There is still lack of knowledge in the use of the composition of internal quality factors for the determination of the physiological age. Temperature is the most influential factor and can be used to regulate the physiological age. The consequences for storage, handling and conducting trials are discussed.

Introduction

The harvested part of the so-called root crops or tuber crops is – in most cases – also used as seed material either as a whole or in parts. The underground organs called as tubers, rhizomes, corms or bulbs are of different morphological origin and vary in size and shape as well as in their spatial relationship with the rest of the plant. All these tubers undergo a process of physiological maturity during the time of growing with the mother plant. After reaching this stage of maturity which can be defined as point zero of the physiological age it follows a period in which all physiological activities have come to a minimum and which is called "dormancy."

The physiological age of a tuber is the state of readiness to grow, and growing is defined as the process to produce a new plant. The physiological age, as such, begins immediately after maturity, which normally falls together with the process of harvesting.

The time between maturity and readiness for sprouting is called the dormancy period which is, by some authors (Claver, 1953; Krijthe, 1962; Madec, 1963), divided into two parts, i.e., the "rest period" and the "dormancy period" which can be also called the state of "latent readiness to sprout."

Generally, dormancy is observed in all kinds of tubers, i.e. potato, cassava, yam, sweetpotato, even in cocoyam and taro.

While for ware tubers, the problem lies in the prolongation of the storage period for better marketing, for seed material, the problem is the internal quality to produce an optimal yield. This applies principally to all kinds of vegetative planting material. Here the discussion will be concentrated on tubers for seed, like potato and yams, cocoyam and taro, and to a lesser extent sweet potato.

The knowledge of what happens in the tuber during the dormancy period is still small. But recent investigations on potato give us some information.

According to Muller (1975), the tuber first enters a phase of physiological re-adjustment during the transition from "physiological maturity" to dormancy. During this readjustment, the tuber is in an unstable state and reacts strongly to all possible environmental influences.

After maturity, when the buds (eyes) of the tuber are totally resting, is (in a certain sense) the point zero of the physiological age or the start of physiological aging as a process. The inhibitors of bud sprouting are fully effective. From now onwards, physiological aging begins even under "ideal" storage conditions where the metabolism of the tuber (as plant organ) is minimized, i.e., the sprout inhibiting hormones become increasingly inactivated and certain internal changes of the chemical composition take place.

The end of physiological aging as a process is reached when the tuber is unable to sprout any more or a new plant has been developed. This can occur either in the field or by premature tuber formation.

Some authors (Claver, 1953; Reust and Munter, 1975) designate the stage which follows the dormancy period as the incubation time. In other words, incubation time begins with the stage of visible sprouting and ends with the production of a new plant or – in the store – with premature tuber formation. In any case the end of incubation period also means the end of physiological aging. The incubation time is the second part of the process of physiological aging.

It is quite obvious that the potato tuber has best been studied with respect to physiological age. For others tubers relatively little has been done. Campell *et al.* (1962) found that sprouting of yam tubers was related to the level of glutathione present in the tuber and many authors later on refer to these findings.

Determination of the physiological age

The following statements are based mainly on research on potato tubers. But various research findings (Campbell *et al.*, 1962; Cibes and Adsuar, 1966; Coursey, 1966; Coursey, 1967; Haynes *et al.*, 1967; Ferguson *et al.*, 1969; Tsuno, 1970; Onwueme, 1978) show the importance of the quality of seed material for the development of the plant and the yield of all kinds of tuber crops. A part of the quality of the seed material is its physiological age. The research findings on potato can help one to understand the metabolic processes in other tubers too and can encourage similar research projects.

It is possible to determine the physiological age of a seed tuber

- before planting; to determine what physiological age a seed tuber had on the day of planting; and after planting.

There are two ways to determine the physiological age:

- external, i.e., on the phenotype of the tuber and/or of the plant growing from the tuber;
- internal, i.e., determining the composition of the tuber with regard to organic acids, sugars, hormones etc. by chemical methods.

Before Planting, External

After maturing, the metabolism of the tuber is still functioning, i.e., respiration and evaporation take place even under "ideal" storage conditions. Both mean loss of water with the result that the skin starts to shrink.

Taking into account the fact that physiological aging of the tuber proceeds during all foregoing processes, the state of physiological age can be determined according to the following characteristics: skin shrinkage, sprout number, sprout length, branching of sprouts, hardening of sprout tips, and premature tuber formation.

In the order given above, a progressed state of physiological age has to be assumed.

An example is given in Table 1 (Carls, 1976), which shows how sprout number, sprout length, branching of sprouts, and skin shrinkage can give an idea of the differences in physiological age on a given data.

Following Muller's (1975) description of metabolic activities (Fig. 1) after – what he calls – "physiological maturity" in the field, exactly this will be the point zero of the physiological age of a tuber. The three lines during the phases G, H and I showing different intensity of metabolic activities indicate simultaneously the physiological age: The higher the line, the faster is the process of physiological aging; the lower the line, the younger remains the tuber physiologically speaking.

After Planting, External

If it seems to be possible to determine the physiological age before planting as an absolute state, after planting it can be determined only by comparison. Table 2 shows the reaction or the growth habit of a plant growing from a physiologically young and a physiologically old tuber, respectively:

Growth and yield performance are influenced by the physiological age of the seed potatoes (Madec, 1956; Perennec and Madec, 1960; Madec and Perennec, 1962; Krijthe, 1962; Toosey, 1963; Kawakami, 1952; 1962; 1963; Iritani, 1968; O'brien and Allen, 1975; Munster, 1975). If a physiologically old tuber is planted, the growth processes are accelerated and the prospects for a high yield are lower. According to Kawakami (1952, 1962, 1963), the tuber should display at planting time a "favorable physiological age" which represents the stage of greatest functionability of the tuber.

Internal

In the course of research to find the internal substance which influence the potato products during processing, many substances were analyzed and quantitatively determined. It was found that various kinds of sugars, organic acids, vitamins, volatile aroma substances and others change in quantity and relation to each other from the time of maturity onwards depending on the environmental conditions in the storehouse, mainly temperature.

The question is whether these findings can be used to determine the physiological age of tubers. Since the external characteristics can be used precisely only in a comparison of two or more tuber lots, a scale for quantification of the physiological age on the basis of internal characteristics such as those given by Muller (1975) (Fig. 2) would be welcomed. Under defined conditions, as the time of storage becomes longer, the content of sucrose rises distinctly and that of malic acid slightly whereas the content of citrate decreases slightly and vitamin C rapidly.

Influences on the Physiological Age

It has been observed that tubers ready for sprouting or even with sprout tips already developed can be found before the vegetation period of the plant is over, which means that such a tuber has not undergone a dormancy period. This occurs when high temperatures prevail during the last part of the growing period. It is the most typical example for temperature influence on physiological age.

Temperature

The most important factor in this respect seems to be the temperature. As already mentioned, the temperature influence begins already during the last part of the growing period in the field. Tubers already sprouting at the time of maturity or harvest are physiologically older than tubers which are not sprouting.

Temperature can occur in various times: with a small or a large gradient between day and night (maximum and minimum), constant for longer periods, or with periodic variations. Its influence on the physiological age of potato tubers differs correspondingly.

High temperature either constant or with variations will always accelerate the metabolism and, therefore, advance the physiological age. Medium temperatures will also further the process but at a much slower rate.

The definition of "high", "medium" and "low" temperature depends entirely on the crop and differs very much. While potato has its optimal storage temperature between 2 and 4°C and "high" temperature to break dormancy is about 20°C, the same data for yams are 10-15°C and 30°C, respectively. Sweet potato has its optimum somewhat higher than yam, and its dormancy period is shorter due to inherent factors (Tsuno. 1970).

If sprouting is induced by a temperature shock, the sprouted tuber can still be physiologically young. If sprouting is induced by a long lasting medium temperature, the sprouted tuber can become physiologically older.

It can be stated that the regulation of the temperature in the store is a good instrument in the hand of the grower to influence the physiological age of the tuber but only within the limits of the heredity of the variety and the value of origin.

Light

Light can influence the plant metabolism as exposure and/or as photoperiod. There is no evidence as yet that the photoperiod has any effect on the physiological age of potato tubers. It is also well known that light as such and light quality influence the sprouting of tubers but only in combination with temperature. As long as the physiological age is determined mainly according to external, phenotypical characteristics, it seems to be difficult to isolate the influence of light. The combination of light and temperature also makes it difficult to determine the physiological age according to the form of the sprouts, as mentioned earlier.

Relative Humidity

The role of the relative humidity in storage is well known with regards to its influence on evaporation. Low relative humidity will increase the evaporation with the danger of shrinking. In so far, there is possibly an indirect influence on the physiological age.

Conclusion

A tuber as a vegetative - living - organ reacts to all kinds of external influences always in the direction of aging. It is impossible to reverse this direction but it is possible to slow down the process of aging. The main influential factor - as we have discussed - is the temperature which affects the tuber already during its last part of growing period in the field, then during storage, transport and any operation of handling. These treatments have to be done carefully to maintain the quality of seed tubers with all consequences for development and yield.

There is no principle difference between seed tubers of various crops although the morphological origin and, therefore, the process of sprout building differs.

Specially to be mentioned is the problem of breaking the dormancy to have seed tubers ready for planting earlier than the normal ecological conditions on a given place allow. Such a treatment could be done successfully by increasing the temperature or by the application of chemicals. For both kinds of treatments, scientific and practical experience is available particularly with respect to potato but also for yams (Campell *et al.*, 1962; Cibes and Adsuar, 1966; Coursey, 1967; Onwueme, 1978; Passam, 1978) and sweet potato (Tsuno, 1970). A forced breaking of dormancy can help to spread the planting season and as a consequence the harvesting period. But it can also help to produce seed tubers of young physiological age with the expectation of higher yield.

And last but not least conclusions have to be drawn for research and trial work. All which has been said shows that results from trials in which different types of planting material are used (e.g. different varieties, different progenies, etc.) can be evaluated only if tuber of the same physiological age are involved. All trial results in which the physiological condition of the tubers is not described are therefore of questionable value.

Especially in the warm regions of low latitudes, it is extremely difficult to meet this demand. However, it is imperative that this condition be fulfilled here as well, because otherwise conclusions for practical work cannot be drawn from the trial results.

This means that in many cases controlled-climate storage facilities must be available for the preparation of experiments, in which the seed material can be also presprouted. The tubers should be sent to other trial sites only shortly before the planned date of planting. Only through the use of seed tubers with the same physiological age can the variability of results from trials be reduced.

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Table 1. Criteria for the determination of the physiological age of seed tubers

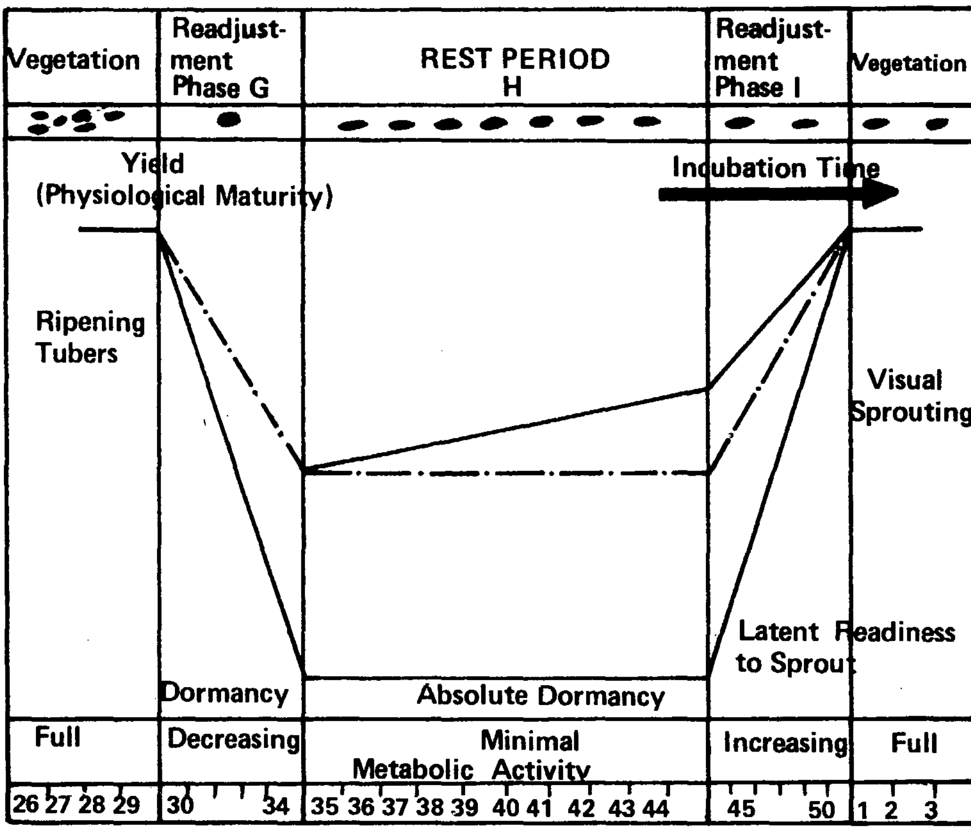
Variety	Generation	Origin	No. of sprouts	Sprout Length cm	Degree of Sprouting 1–2*	Skin Shrinkage 1–9**
Hydra	Cert. Seed	Germany	2.0	1.0	2	9
Hydra	1. Gen.	Pedro	3.0	2.8	1	4
Hydra	1. Gen.	Meepil	4.0	2.5	1	4
Hydra	1. Gen.	Udera D.	2.0	2.4	1	5
Hydra	1. Gen.	H. Plains	2.0	3.2	1	5
Hydra	1. Gen.	Sita Eliya	4.0	2.3	2	3
Rektor	Cert. Seed	Netherlands	2.0	0.5	2	9
Rektor	1. Gen.	Udera D.	3.0	2.7	1	4
Rektor	1. Gen.	H. Plains	2.0	3.1	1	6
Rektor	1. Gen.	Sita Eliya	5.0	2.1	1	5
Arka	Cert. Seed	Netherlands	2.0	1.0	2	9
Arka	1. Gen.	Udera D.	2.0	2.0	1	2
Arka	1. Gen.	H. Plains	3.0	2.7	1	6
Condea	Cert. Seed	Germany	1.0	0.8	1	9
Condea	1. Gen.	Meepil	2.0	2.0	2	8
Condea	1. Gen.	Sita Eliya	3.0	3.0	2	7

*Degree of Sprouting 1 = weak and irregular
2 = strong and regular

**Skin Shrinkage 1 = greatly shrinked
9 = no shrinking

Table 2. Reaction or the growth habit of a plant growing from a physiologically young and old tuber.

Character	Physiologically Young	Physiologically Old
Emergence	later	earlier
Growth Speed	slower	faster
Stem number	less	more
Growing height	higher	lower
Vegetation period	longer	shorter
Tuber size	greater	smaller
Tuber yield, early	lower	higher
end	higher	lower
Resistance to emergence defects	higher	lower
Soil-borne fungus diseases	higher	lower



normal course

increasing metabolic activity by early harvest under unfavourable storage conditions in the readjustment phase "G"

too high metabolic activity under unfavourable storage conditions.

Fig. 1. Changes in the Metabolic Activity of the Potato Tuber from the Time of Physiological Maturity until Sprouting

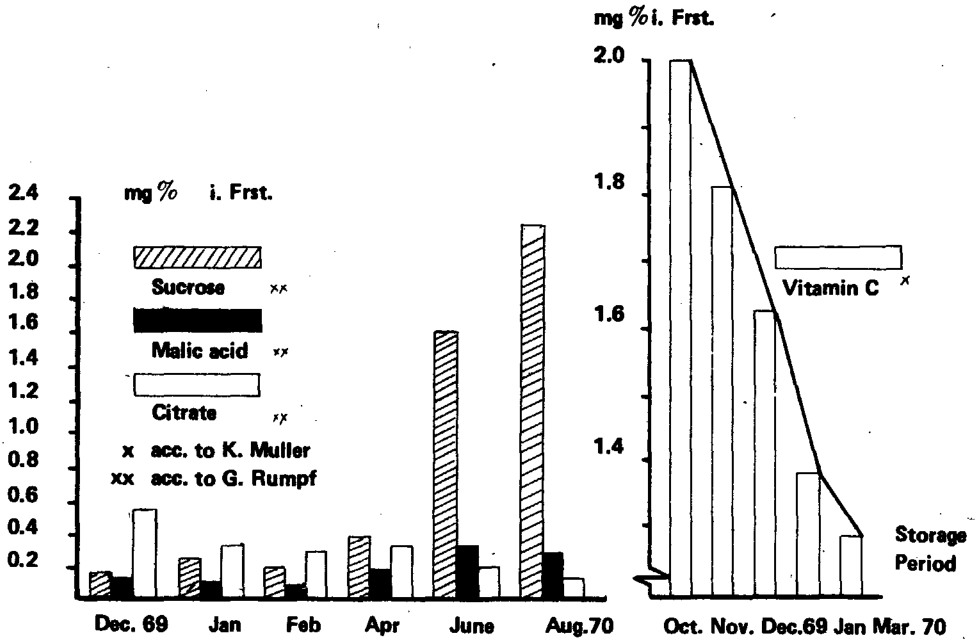


Fig. 2. Constituent Substances as Possible Criteria for the Determination of Physiological Aging in Seed Tubers