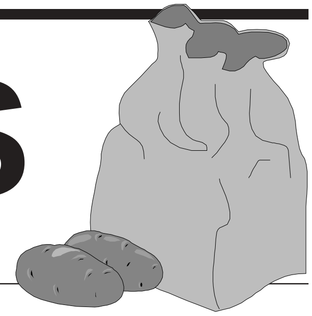
PHREC 2004-05a

NEBRASKA

POTATO EYES



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Physiological Aging of Seed Tubers

For many decades, almost since the discovery of hormones in the late 19th century by Fritz Went and Francis Darwin (son of Charles), biologists realized that organisms, plant and animal, age internally at different rates that is not accounted for by time alone. Physiological aging is affected by two factors influencing internal biochemistry especially hormones: genetic predisposition and environmental stress. Since potato is grown from cloned stem tissue (tubers), genetic predisposition is at the level of cultivars (van der Zaag and van Loon, 1987). Environmental stresses in the field are primarily moisture, temperature, nutrients, pest injury, and mechanical damage. In storage, stresses are temperature, moisture, aeration, bruising, and disease.

Physiological aging in potato encompasses two types or models, vine during the growing season and tuber during the storage season. Physiological aging in vines is calculated based on daily air temperature fluctuations and is used to predict when plants are susceptible to infection by early blight (*Alternaria solani*), an opportunistic disease that attacks senescing plants. The other type of physiological aging concerns the viability of tubers used for seed. This is broadly defined as "... physiological status of the tuber as it affects productivity." (Bohl et al., 2003) or "... internal age of the seed (tuber) resulting from biochemical changes..." (Bohl et al., 1995). It is tuber aging that is the subject of this discussion.

Although physiological aging of tubers may occur during the growing season due to stress, it is poorly understood and not quantifiable. However, tubers from plants that died prematurely tend to be physiologically older. Soil temperature at the end of the season clearly can play a major role; high soil temperatures under dry conditions in sandy soils can stimulate sprouting before harvest. The only way to measure season-stimulated physiological aging of tubers is to conduct a bioassay determining dormancy and sprouting characteristic. The best general indication is to look at the field history of the seed lot in comparison to previous years' seed lots' performance. However, the major aging of seed tubers occurs during storage.

During tuber storage, the primary influence on physiological aging is temperature. Higher storage temperatures are associated with greater physiological aging. The exact relationship is not yet established but a correlation exists; however, there is no predictor of aging. There is no direct measure of aging although a heat accumulation model is sometimes used. So to determine the age of a seed lot samples are removed and bioassayed for morphological stages of aging.

Inside this issue...

Stages of Physiological Aging in Tubers: There are five stages of tuber physiological aging based on sprouting (Iritani et al., 1983; Schrage, 1999a).

I. Dormancy — This is sometimes considered a pre-aging stage (Bohl et al., 2003). When tubers are harvested, under normal circumstances, i.e., no heat sprouting, the eyes (or buds) are in a state of dormancy. Dormancy is a physiological state induced primarily by a hormone called abscisic acid (ABA) that enters tubers from the vine during the season during tuber growth. Dormancy is characterized by a period during which sprouting will not occur even under optimal conditions. Dormancy is broken when the amount of ABA in the eyes decreases through metabolic breakdown to a level that allows the eyes to respond to conditions favoring sprouting. [This is the same hormonal mechanism involved in seed and bud dormancy.] In physiological aging models, tuber aging does not commence until dormancy is broken.

II. Apical Dominance — Young seed is characterized by the exhibition of a dominant eye over the other eyes, that is, suppressing the sprouting of other eyes. The suppressing eye is at the apical end of the tuber or "bud" end which is the furthest eye from where the tuber was attached to the vine. This physiological phenomena is termed apical dominance and is common in the plant kingdom, e.g. suppression of growth of lower branches by the uppermost branch. It is mediated primarily by the hormone, indole acetic acid (IAA), an auxin (Kumar and Knowles, 1993). In the case of potato tubers, the eye and young sprout produce IAA which travels down the tuber suppressing the other eyes from sprouting. This suppression is dependent on IAA concentration as dormancy is dependent on ABA concentration. In both these phenomena, there are hormones, cytokinins and gibberellins, which can build up and counteract ABA and IAA. The result is that physiologically young tubers produce one or two main stems or low stem number per acre. There is initially one sprout at the apical end and later a second sprout may appear from the eye furthest from the dominant eye as the IAA level is lower.

It is important to note here that the genetic makeup of a cultivar is the basis of how much ABA and IAA are produced, how sensitive are tissues to them, how fast they are broken down, and how much and when counteracting hormones are produced. Environment influences all of these but the basis is genetics.

III. Multiple Sprouting — Older seed tubers ("middle-aged") are characterized by the loss of apical dominance between eyes, i.e., effective IAA levels in tubers are decreased. This develops gradually in time but the time can be shortened by heat. Or, the dominance can be disrupted by cutting the tuber and thereby breaking the translocation path of IAA in the tuber. Removal of the apical sprout will also disrupt apical dormancy although in young tubers, it may be reinstated by the next eye closest to the apical end. Therefore, this stage is characterized by the

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Figure 1. Little tuber disorder.

appearance of several eyes sprouting along the tuber resulting in several main stems per plant. Main stem number correlates with yields and will be discussed later (Iritani et al., 1983).

IV. Branching — As seed tubers age further, there is a breakdown of apical dominance within the sprout, that is, the dominance effect of the tip of the sprout, where IAA is produced, on branch buds below has broken down. The result is that sprouts of physiologically old seed tubers are branched. These branches may be weak, referred to as “hairy.” Or, there may be a proliferation of small stolons and a large tuber set that will not be poorly maintained.

V. Little Tuber Disorder — The IAA mechanism is now so broken down that not only do sprouts proliferate their branches into underground stolons but these do not grow much and form tiny tubers quickly. Some cultivars like Russet Norkotah are prone to this (Figure 1).

Performance and Characteristics: Plants growing from seed tubers of different physiological age perform differently (van der Zaag and van Loon, 1987). Differences are summarized in Table 1. Figure 2 presents data on Russet Burbank (Iritani et al., 1983). Storage temperature regimes were converted into heat accumulation units [p-days = (daily storage temperature in ^{o}F - 39^{o}F) x number of days stored]. The data presented is based on seed purchase on October 31 and planting on March 31, and underestimates the actual exposure of tubers to physiological days. Figure 3 adapts unpublished data from Australia on cv. Kennebec (Grice, 1993). It demonstrates that aged seed emerges earlier, grows faster, yields higher early, and yields less later than unaged seed. Figure 4 illustrates the shift in tuber size distribution in relation to stem number per plant as affected by seed tuber aging in storage (Knowles et al., 2003).

Table 1. Performance Characteristics Associated with Physiological Age of Seed Tubers. (Iritani and Thornton, 1984)

Characteristic	Young Seed	Old Seed
emergence	slower	faster
stand	greater	lesser
early vigor	greater	lesser
foliage	more	less
stems/plant	less	more
tuber formation	later	earlier
formation period	longer	more uniform
tuber number	less	more
tuber bulking	longer	shorter
tuber sizing	larger	smaller
senescence	later	sooner
early harvest yield	lower	greater
late harvest yield	greater	lower

Bioassays and Age Estimations: The simplest bioassay is to take sample tubers from a lot and place them in the dark at

Figure 2. Relation of physiological age of tubers to stem number and yield, cultivar Russet Burbank. (modified from Iritani et al.,1983)

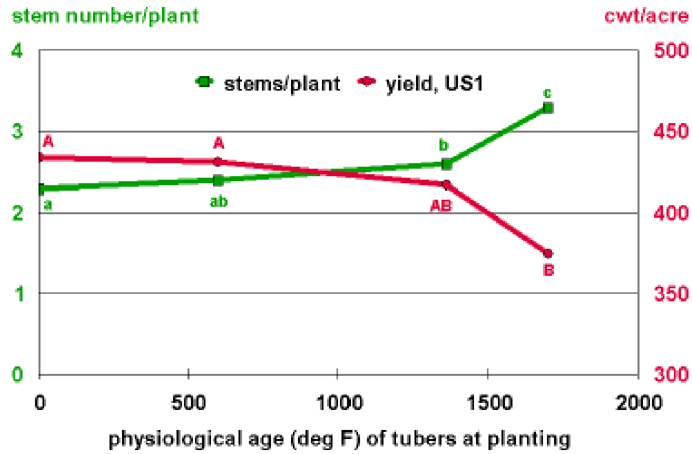


Figure 3. Relation of physiological age to plant height, cultivar Kennebec. (adapted from Grice, unpublished)

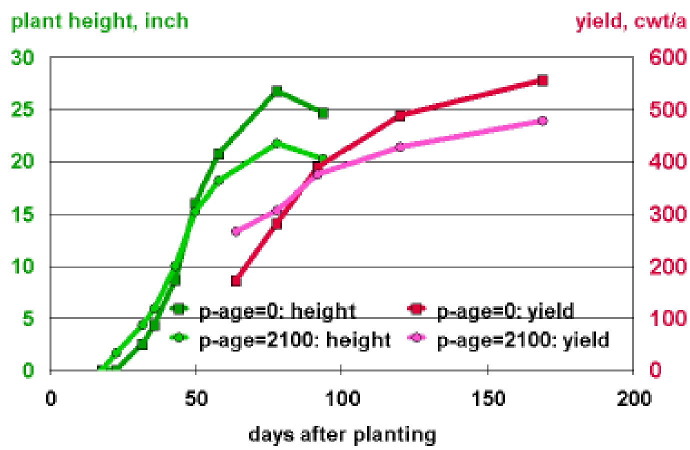
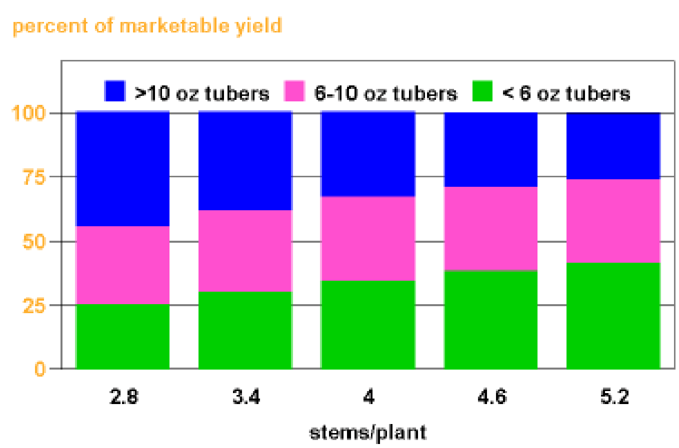


Figure 4. Relation of stem number to distribution of tubers, cultivar Ranger Russet. (modified from Knowles et al., 2003)



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room temperature. After a few weeks, observe the sprouting pattern and match this with their sprouting (Bohl et al., 2003 van der Zaag and van Loon, 1987). Another determination is called the physiological age index (Caldiz et al., 2001) but this method can take several months. It is not practical for growers but may be useful for research. A laboratory test that takes a month involves weighting and counting sprouts (van Ittersum et al., 1990). There is no current method to quantify aging. However, in the future it is hoped that physiological aging of tubers can be measured biochemically. One potential age marker is 2-methyl butanol (Knowles et al., 2003).

Since bioassays take time at least a few weeks, they present a kind of "delayed exposure snap shot" of aging. For an immediate estimate on the relative physiological age of seed lots, a heat accumulation calculation is commonly used (Jenkins et al., 1993; Knowles and Botar, 1991). This method is based primarily on temperature exposure over time. The equation is p-age (°F) = (average daily storage temperature minus 39°F) times number of days between dormancy break and planting. [In °C, replace 39°F with 4°C.] One weakness of this method is that it does not take into account chronological aging, i.e., no aging at the base temperature, which, however, does occur (Caldiz et al., 2001). The time-temperature data reported by Iritani et al., 1983 and used for Figure 2 were transformed into physiological (°F) day units for comparisons.

Management and Markets: In storage, the major factor that progresses tubers through the stages of aging is temperature which can be manipulated to produce the desired age of tubers at planting (Schrage, 1999b). Planting older seed of cultivars that tend to oversize such as Yukon Gold may have advantages to improve uniformity increasing the number marketable sizes especially for early markets (Asiedu et al., 2003). This may also be true for seed production where a smaller tuber size profile might be preferred. Some cultivars are not benefitted by aging such as R Norkotah while others might such as Yukon Gold and Shepody. To age seed, store at 38F then before planting store for 2 to 6 weeks at 55-60F. To hold young seed, store at 38F and warm to 45F just before cutting and plant in soil about the same temperature as the tubers. Cutting tubers breaks apical dominance between eyes releasing eyes to sprout. De-sprouting may result in more stems and smaller tubers as this eliminates apical dominance.

Because young seed emerges slower, there is a greater chance of seed decay and cankers (stem and stolon). Planting young seed in warmer soil can hasten its sprout emergence and growth. Do not plant seed right out of cold storage into soil as this will promote condensation of the seed and increase decay. Warm seed to 50-60F for a few days and plant in soil slightly cooler. This will add some physiological age to the seed tuber or pieces. Seed planted in light sandy soil which warms rapidly tend to produce more stems, set more tubers and result is smaller harvested tubers. Extra N starter can partially overcome the effects associated with aging that is N can partially mimic young seed characteristics. Note that later planting tends to produce more stems per plant and have lower yield.

Sprouting of tubers under light produces short, tough, green sprouts. Green sprouting or chitting enhances emergence, tuber formation, vine size, and earlier maturation as much as two weeks. It is used for early harvested yields. Light requirement is low and stacking trays are often used. Chitted tubers are planted with cups not picks to avoid sprout damage.

When a longer growing season is possible and large tubers are marketable such as bakers and French fryers, young seed just about to produce a few sprouts may be desired. On the other hand, for an early fresh market, older seed at the multiple sprout stage may be more desirable to get a higher yield early and a quicker vine senescence. Older seed might be more desirable for seed production where a smaller tuber profile at harvest may be more desired than bulk yield. To decide what is the optimal physiological age to plant, one must take into consideration the cultivar's characteristics, the market for the crop and the anticipated conditions during the growing season.

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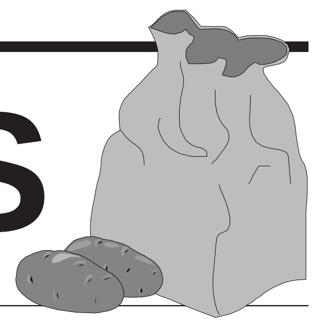

**The Nebraska Potato Eyes is on the WWW at:
www.panhandle.unl.edu/peyes.htm**