AN ABSTRACT OF THE THESIS OF

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Title: Physiological Ageing of Russet Burbank Seed Potatoes: Effects on Seed Tuber Quality, Plant Development, and Yield

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During physiological ageing of seed potatoes, the stored tuber undergoes certain biochemical changes which cause the breaking of dormancy and the initiation of bud growth. The ageing process can be manipulated through storage temperature and duration. Higher temperatures usually accelerate seed tuber ageing. In order to define the process of physiological ageing and develop optimum ageing treatments, seed potatoes were stored at 4.4°C and then warmed to either 10.0°C (1984) or 15.6°C (1985) for 0, 2, 5, and 8 weeks prior to planting. Levels of total, reducing, and sucrose sugars, respiratory activity, free amino acids, soluble protein, and phosphorylase activity were monitored weekly. Field studies were conducted to determine the effects of seed storage temperature and duration on plant development and yield. Three sites with different lengths of growing season were selected.

Warming seed to 10.0°C and 15.6°C greatly accelerated sprouting ability in storage. Apical dominance was evident in seed which had been stored for long periods at these elevated temperatures. Total, reducing, and sucrose sugars declined during storage at 10.0°C, indicating both a suppressing effect of elevated temperature on sugar fractions and increasing metabolic energy demands. Conversely, both reducing and total sugars increased over time in seed held at 4.4°C, eventually reaching a constant level. Sucrose declined to a minimum and then fluctuated randomly with additional time at this temperature. Phosphorylase activity increased dramatically approximately five weeks after testing began in tubers stored at both 4.4°C and 15.6°C. Activity then declined two weeks

later and remained constant throughout the study. Free amino acids decreased to a low level during storage at both temperatures, reached a constant state, and then slowly increased with additional storage time. Soluble protein levels initially increased during storage, but then declined. Respiratory activity, as indicated by the production of formazan, remained fairly constant throughout storage at both temperatures.

Plant stands were not affected by storage temperature. Seed warmed to 10.0^{o}C and 15.6^{o}C generally emerged faster and established a canopy earlier in the season than seed held at at 4.4^{o}C. Differences in plant size and canopy density diminished rapidly as the season progressed. Numbers of aboveground stems per hill increased with time at 10.0^{o}C and 15.6^{o}C. Storage treatment did not affect time of tuber set or plant senescence.

Storage treatments significantly affected yields at one location in 1984. Seed held continuously at 4.4^{o}C produced more undersized tubers than any other treatment at Corvallis (medium length season).

Treatments significantly affected yields at all three sites in 1985. At Powell Butte (short season), seed held at 4.4^{o}C yielded more than seed warmed to 15.6^{o}C, and produced significantly higher yields of U.S. No. 1 tubers than any other treatment. Seed warmed at 15.6^{o}C for 2 weeks yielded significantly more culls than any other treatment. At Corvallis, (medium length season) seed stored at 15.6^{o}C for 5 weeks produced significantly higher total yields than any other treatment. Yields of U.S. No. 1 tubers at Hermiston (long season) were higher for seed held continuously at 4.4^{o}C, while seed warmed at 15.6^{o}C for 5 weeks produced more undersized tubers than any other treatment.

It appears that length of growing season, plant growth patterns, and plant types combine to determine yield response to seed conditioning. Seed conditioned at higher temperatures emerged early, produced large numbers of aboveground stems per hill, and performed best in an area with a medium growing season, but did not appear to be well suited for areas of either short or long seasons. Seed held continuously at 4.4^{o}C emerged late, produced few above-ground stems per hill, and produced higher U.S. No. 1 yields than seed conditioned at the higher temperatures, in areas with a long or short season. Powell Butte (short season) experienced a late spring frost in 1985. It is possible that due to less advanced foliage growth at the time, plants from seed held at 4.4^{o}C were not as severely damaged as the plants from warmed seed, explaining high yields produced by cool stored seed in this short season area.

PHYSIOLOGICAL AGEING OF RUSSET BURBANK SEED POTATOES: EFFECTS ON SEED TUBER QUALITY, PLANT DEVELOPMENT, AND YIELD

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INTRODUCTION

The Russet Burbank variety (Solanum tuberosum L.) is a major source of income for most potato growers in Oregon. Seed quality is extremely important in determining yields and profits. Good quality seed is disease and bruise free, of correct size, and without varietal mixtures. Several researchers (Kawakami, 1962, 1963; Toosey, 1963; Iritani, 1968ab; Susnoschi, 1974,1981ab) have proposed that the physiological age of seed tubers at planting is also a determining factor in performance. Age refers to the metabolic status of the tuber, and can be thought of as the relative readiness of the tuber for sprout initiation and plant growth. The physiological age of seed tubers affects sprout growth and development, which in turn affects tuber set, yield, and quality. Exposing seed to higher storage temperatures accelerates the ageing process (Perennec and Madec, 1980). Variety plays a major role in tuber response to storage conditions (Wright and Peacock, 1934). There is currently no standard recommendation for conditioning Russet Burbank seed in Oregon. This study was designed in part to determine optimum storage regimes for Russet Burbank seed potatoes for three areas (Hermiston, Corvallis, Powel Butte) representing different lengths of growing season.

The rate of physiological ageing was altered by warming seed tubers stored at 4.4^{o}C to either 10.0^{o}C (1984) or 15.6^{o}C (1985) for 0, 2, 5, and 8 weeks prior to cutting and planting. Because metabolic changes associated with the breaking of dormancy are not well understood, changes in soluble protein, phosphorylase activity, free amino acids, sugars, and respiratory activity were chosen as indicators of metabolic activity and were monitored during storage. Attempts were made to relate plant stands, rate of emergence and senescence, stem number per hill, tuber set, and foliage vigor to productivity.

LITERATURE REVIEW

Importance of Seed Quality at Planting

Potato yields are limited by the potential of the seed used. Smith (1968) states that varietal purity, diseases and bruises, and tuber size are important factors in determining the performance of seed potatoes. Many of these factors are visually apparent. Cultural and storage practices used to produce and hold the seed crop influence yield (Wurr, 1978). Cultural practices and storage regimes represent an accumulation of events which influence the potential yield of seed, but effects cannot be visually evaluated.

The existence of a physiological age factor was evident even in early studies. Many researchers (Appleman, 1924; Rosa, 1928; Stuart et al., 1929; Hartman, 1934; Smith, 1937) recognized the importance of considering sprout growth, development, and vigor in forecasting the viability and performance of seed. Several years later the term "physiological age" arose (Perennec and Madec, 1960; Kawakami, 1962; Krijthe, 1962; Toosey, 1964; Iritani, 1968a) to explain differences in sprout development associated with the physiological status of seed.

The physiological state of a seed tuber at planting should be considered a quality factor, since it affects seed performance (Toosey, 1963). The more obvious physical qualities such as size, disease and bruise defects, varietal purity, and general soundness, combine with the physiological status to determine yield potential.

The Concept of Physiological Ageing

Toosey (1964) defined physiological age as "the physiological state of a tuber at any given time" and suggested that it is expressed by the degree of sprout development. Perennec and Madec (1960), on the other hand, described physiological ageing as an "evolution proceeding within the storage tissues according to a defined sequence". Krijthe (1962) attempted to provide a consistent measurement of tuber age by dividing sprout development into four stages - the one sprout stage, the multiple sprout stage, the branching stage, and the small tuber formation stage. She noted that the physiological age of the tuber increases with each stage of sprouting.

The use of sprouting capacity as a measurement of physiological status is subjective, but remains the only visible indicator of the ageing process. Seed tubers which show prominent sprout development are said to be "physiologically old", while seed tubers displaying little or no sprout development are said to be "physiologically young" (Wurr, 1978).

Conditions under which the seed is grown, chronological age, and storage environment all affect physiological age. Stressful conditions, such as high temperatures during the growing season influence seed performance the next year (Went, 1959). Iritani (1968b) noted that seed grown under cool temperatures was physiologically young. Rosa (1928) reported that the more mature a tuber was at the time of harvest, the shorter was the time period needed for sprouting to occur. Kawakami (1963) described seed stored for prolonged periods of time (increasing the chronological age) as physiologically degenerated. Seed that is planted before the proper chronological age is reached is said to display juvenile degeneration (Kawakami, 1962). Chronological age affects physiological age; however, seed that is harvested at the same time can be aged at different rates by exposing the tubers to different storage environments (Wurr, 1978).

Storage environment is the one variable affecting physiological age that can be most easily controlled. The tuber is greatly responsive to storage temperature, but humidity and light in storage reportedly have little effect on sprouting ability (Davidson, 1959). Burton (1958) reported that CO_2 levels had no effect on sprouting, while increased O_2 levels decreased the time needed for sprouting to occur. Temperature is therefore the major storage factor modifying the length of time between harvest and sprout growth (Davidson, 1958; Iritani, 1968b; Perennec and Madec 1980; Susnoschi, 1981ab). The ageing process accelerates with increasing storage temperature (Perrenec and Madec, 1980).

Why elevated temperatures increase physiological ageing and shorten the period to sprout growth is not quite understood, mainly due to the fact that the dormancy mechanism of potatoes is not clear (Wurr, 1978). Several theories have been proposed.

Regardless of the ageing mechanism, it is still possible to influence the rate of ageing. Emilsson (1949) and Susnoschi (1981b) report that sprouting behavior is a varietal characteristic that is influenced by storage conditions. Wright and Peacock (1934) reported shortened dormancy periods for all varieties subjected to elevated storage temperatures. Russet Burbank seed tubers have a natural dormancy of 12 to 16 weeks (Kleinkopf and Westermann, 1983); however, temperature in storage can modify dormancy duration. Iritani (1968b) reported that elevated storage temperatures did shorten the dormancy period of Russet Burbank seed tubers.

Physiological ageing is a natural process that allows the tuber to emerge from a state of no visible growth potential to a state of visible sprout growth and development. Sprout morphology and degree of development, as suggested by Krijthe (1962), can be used as criteria to evaluate the extent of the ageing process. The ageing process is influenced by growing conditions, tuber maturity at harvest, and chronological age. Storage environment appears to influence the ageing process to a greater extent than all other variables, with temperature being the major modifying factor.

Influence of Storage Temperature On the Physiology and Metabolism of Seed Tubers

Tuber dormancy is defined by Emilsson and Lindblom (1963) as "the period during which tubers will not sprout or break down physiologically when stored at some temperature below the optimum for sprouting". Davidson (1958) has a similar definition, describing dormancy "as the time required for tubers to produce sprouts at sub-optimal conditions". Perhaps Burton (1963) has a more precise definition. He describes dormancy as "the lack of consistent bud growth due to chemical and physical conditions within the tuber" and stresses that storage environment influences these conditions to a great extent.

Internal mechanisms triggering the breaking of dormancy and the initiation of bud growth are still not entirely understood. Several theories have been proposed, one being that necessary metabolites are temporarily unavailable for bud growth (Burton, 1963; Perennec and Madec, 1969; Dyson and Digby, 1975). The consensus is that dormancy is controlled by a shifting and complex balance of growth inhibitors and promoters, probably hormonal in nature (Hemberg and Larsson, 1961; Burton, 1958,1963; Bruinsma and Swart, 1970; Moorby, 1978).

Elevated storage temperatures shorten the dormancy period of seed tubers. The length of dormancy depends on variety, temperature, and duration in storage (Loomis, 1927; Rosa, 1928; Wright and Peacock, 1934; Emilsson, 1949; Davidson, 1958; Krijthe, 1962; Susnoschi, 1981b). Upon breaking of dormancy, sprouts begin to grow and differentiate and the respiration rate of the tuber increases (Burton, 1978; Dwelle and Stallknecht, 1978). Starch is degraded (Cutter, 1978) and serves as the primary substrate for increased respiration and bud growth (Norton, 1963).

Sucrose, fructose, and glucose are the major sugars found in white potatoes (Schwimmer et al., 1954). Levels of these sugars are affected by starch breakdown and sprouting (Smith, 1968).

Emilsson (1949) reported a decline in sucrose and reducing sugars as sprouting occurred as did Dimalla and Staden (1977). Van Vliet and Schriemer (1963) however, reported a rise in sucrose levels following the breaking of dormancy. It is important to note that carbohydrate fractions are very sensitive to temperature, irrespective of stage of dormancy. Starch is broken down and sucrose levels increase with cold temperatures, while tubers are still dormant (Pollock and ap Rees, 1975). Enzymes activated by low temperatures convert sucrose to reducing sugars (Smith, 1977). These conditions can be reversed by exposing the tubers to a higher temperature (Pressey, 1969; Iritani and Weller, 1977; Weaver et al., 1978).

Warm storage temperatures increase metabolic rates, using energy derived from starch reserves. Starches can be broken down by either hydrolytic or phosphorylytic enzyme systems. Amylase and phosphorylase are reported to be responsible for formation of sugars during cold temperature storage (Smith, 1977).

Several views have been forwarded to explain systems involved in sprouting. Edelman (1963) theorizes that phosphorylase and a debranching enzyme break down starch, which is then mobilized as glucose-1-phosphate (Norton, 1963). Emilsson and Lindblom (1963) suggest that amylase is also involved. Clancy et al. (1968) report that phosphorylase and phosphatase levels both increased steadily during storage at 49^{o}F for five months.

Elevated storage temperatures not only accelerate sprouting, but also increase the overall metabolic rate of the seed tuber. Protein and amino acid levels change during bud initiation. Szalai (1957) reported a rise in free amino acid levels during sprouting, which reached a maximum two weeks after sprouting began. Emilsson and Lindblom 1963) also reported an increase in amino acid levels as the tuber emerged from dormancy. According to Talley et al. (1964) proline shows a marked increase at sprouting. Protein levels, particularly the albumin fraction, were shown to increase up to the time of sprouting and then to decline (Levitt, 1954; Emilsson and Lindblom, 1963). These results compare well with the increasing levels of free amino acids found during sprouting (Szalai, 1957; Emilsson and Lindblom, 1963). Shih and Rappart (1970), in addition, found an increase in protein synthesis at the termination of dormancy. These reports indicate that synthesis of new proteins and degradation of old proteins are simultaneously occurring when dormancy ends. Apparently, storage proteins are degraded to free amino acids that are transported to sites of active growth for the synthesis of new proteins for sprout growth (Emilsson and Lindblom, 1963). A transitory increase of free amino acids and soluble albumin with sprouting is to be expected.

Increases in metabolic activity may be detected by measuring the metabolic reducing activity present in the tissue. A test (TZ) which uses 2,3,5-triphenyl tetrazolium chloride as an indicator to quantify tissue viability is a standard practice in grass and cereal seed testing (Grabe, 1970). Waugh (1948) reported using the TZ test for testing the viability of trees and shrubs and it has been used as a rapid method for estimating dormancy in gladiolus cormels (Roistacher et al., 1953). The dormancy or germinability of the cormels was evaluated by visually rating the intensity of color.

Sacher and Iritani (1982) have proposed using the TZ test as a tool to measure the physiological status of seed tubers. Because reaction rate was significantly correlated with temperature treatments and yield of U.S. No. 1 tubers, they believed that the test could be used as an indicator of metabolically active tissue. This test could theoretically be used to determine the degree of physiological ageing which has occurred within a seed tuber. Experiments to determine the substances responsible for the reduction of 2,3,5,-triphenyl tetrazolium chloride and the formation of formazan, suggest that several physiologically active plant enzyme systems are involved, and that dehydrogenase together with reduced coenzymes are responsible, but it is possible that other reducing plant substances may be involved (Roberts, 1951).

Effects of Seed Conditioning on Plant Development and Yield

Several reports discuss the sprouting tendency of seed potatoes in storage (Lindblom, 1970; Krijthe, 1958,1962; Burghausen, 1962). Most of this research was conducted in Europe, using European varieties. Because presprouting seed is not commonly practiced in the U.S., little work has been done in this area, although Iritani (1968b) proposed that altering seed behavior in this manner could improve yields.

The morphology, size, and number of sprouts, and the rate of sprout growth are determined by the variety (Susnoschi, 1981b) and are influenced by temperature regimes during storage (Headford, 1962). Headford (1962) and Susnoschi (1981a) reported that variable temperatures result in sprout growth rates characteristic of the temperature.

Apical dominance must be considered in evaluating sprout development. Apical dominance is inherent in the tuber, but can be influenced by storage temperatures (Appleman, 1924). Susnoschi (1981b) stresses that apical dominance is relative, and cannot be considered absolute.

High storage temperatures usually result in strong apical dominance, while low temperatures result in a partial loss of dominance (Moorby, 1978; Allen, 1978; Susnoschi, 1981a). Duration in storage also influences sprouting. Seed stored at low temperatures for a longer period of time has a weaker apical dominance than seed stored for a shorter period of time at a high temperature (Dent and Halkon, 1962; Toosey, 1959). McCubbin (1941) and Smith (1936) recorded a greater number of sprouts for tubers stored at high temperatures compared to low temperature storage.

Goodwin (1963) suggests that auxins and inhibitors operate together to maintain dominance of some sprouts over others. If the apical sprout is destroyed, dominance is lost and other buds are released to grow (McCubbin, 1941; Appleman, 1924). Desprouting and cutting seed also break apical dominance and cause more lateral branching and increase the number of sprouts produced per tuber (Holmes and Gray, 1971; Allen, 1978).

It is important to understand the hierarchy of sprout development of a seed tuber. There is an apically dominant eye on each tuber, a dominant bud within the eye, and a dominant sprout within the bud (Iritani and Thornton, 1984). Each bud is capable of producing a sprout under optimum conditions, which can develop into a stem. Stems can be produced from buds directly on the seed piece, from sub-surface branches on the mainstem, and from stolons which have grown vertically (Allen, 1978). All of these are capable of bearing tubers (Allen, 1978). Moorby (1978) discovered that after planting, apical dominance is lessened and axillary buds grow, increasing the number of stems which emerge above ground.

Conditioning seed by exposing it to elevated temperatures increases the physiological age and influences the pattern of stem development through manipulation of sprout growth. As sprout development in storage increases, secondary stems and leaf-bearing stolons also increase (Toosey, 1963; Holmes and Gray, 1971). Generally, high storage temperatures have been shown to result in more stems per tuber after planting (Perennec and Madec, 1980; Iritani et al., 1983; Kawakami, 1962,1963; Smith, 1937). Allen (1978) reported that long periods of sprouting gave few mainstems with many secondary stems and short periods of sprouting gave mainstem densities. Iritani (1968b) found that few stems were produced by physiologically young seed stored at cool temperatures.

Not only are stem numbers affected by high storage temperatures, but so also is the entire development of the plant. Planting physiologically older seed results in a partial displacement of the vegetative period (Toosey, 1963); stems emerge faster, tubers set earlier, and plants senesce earlier than normal (Wurr, 1978; Iritani, 1967,1968b; Fischnich and Krug, 1963; Rozier-Vinot, 1971; Headford, 1962; Davidson, 1958; Toosey, 1962,1963; Smith, 1937; Hartman, 1934). The foliage of plants from aged seed grows faster early in the season and then the growth rate declines earlier than normal (Toosey, 1964). This is because physiologically older seed sets tubers early and synthates are transported to the tuber, rather than to vegetative plant parts (Wurr, 1978). This also causes a lower bulking rate and smaller tubers due to the low LAI (the ratio of leaf area to land area).

Tuber weight is a function of vine growth rate, production and distribution of synthates, tuber initiation, and vine senescence (Bodlaender, 1963). Toosey (1962) showed that tuber number is determined by storage environment, planting date, and mainstem population. Allen (1978) adds spatial arrangement, season, and variety to the list of factors affecting tuber size and number. The number of tubers per stem is a varietal characteristic and is usually constant (Bates, 1935), thus the number of tubers per hill increases in direct proportion to the number of stems per hill (Toosey, 1964). Tuber size is inversely proportional to the number of tubers in a hill (Toosey, 1964; Iritani, 1967; Iritani and Thornton, 1983). Increasing stem numbers results in more, but smaller tubers.

Bremner and Saed (1963) recorded competition between plants for nutrients after planting. Sprouts compete for nutrients from the mother seed piece (Rozier-Vinot, 1971; Kawakami, 1963). Both quantity and quality of yield can be affected by bulking rates and stem numbers per hill. Allen (1978) reports that total yields increase to a maximum with increasing stem density and either decline or remain at a constant level with further increase in density. Iritani et al. (1972) reported that higher average stem numbers resulted in higher yields.

Bodlaender (1963) stresses that daylength, day, night, and soil temperatures, and intensity of radiation all interact to affect yield. Fischnich and Krug (1963) reported that climate can outweigh treatment effects, as did Perennec and Madec (1980), where physiological ageing of seed was not expressed in field conditions. Length of growing season influences the expression of a seed tuber's yield potential. Hartman (1934) and Smith (1937) reported higher yields of U.S. No. 1 tubers with seed stored at warm temperatures. It may be possible to manipulate seed behavior to produce optimum yields in any given length of season. Physiologically young seed might produce higher yields of ware size tubers than aged seed in a long season, due to low stem densities and longer period for bulking (Toosey, 1963,1964; Davidson, 1958). Physiologically older seed might prove more productive than young seed in a short season, due to more rapid emergence and tuber set (Toosey, 1963,1964). Regardless of season length, seed growers might benefit from planting physiologically old seed which would produce a high yield of desirable small tubers, due to high stem densities (Allen, 1978).

All variables involved with growing potatoes, whether for ware or seed, interact to produce final yield. Kawakami (1963) reports reduced vigor and low yields for seed that is planted before or after it has reached its optimum potential. The key is to produce seed which is physiologically ready to express its full potential for a given set of growing conditions.

OBJECTIVES

Primary objectives of this study were; 1) to regulate the physiological ageing of seed potatoes in storage through manipulation of temperature; 2) to monitor physical and metabolic changes occurring during storage; 3) to determine the effects of seed storage conditioning on subsequent plant growth and productivity at three diverse production sites and to develop optimum ageing treatments; 4) to examine potential relationships between various metabolites, seed age, and performance.

The ageing process was manipulated by transferring seed from 4.4^{o}C to higher temperatures for 0, 2, 5, and 8 weeks prior to planting. Physical changes in seed and sprout appearance were recorded at the end of the storage regimes. Levels of sugars, free amino acids, soluble protein, phosphorylase activity, and reducing activity were also recorded weekly. Vine growth was evaluated throughout the growing season to quantify differences due to seed treatments. Three planting sites were used to determine the effects of environment and length of season on growth and yield responses to seed storage regimes.

CH 1

Effects of Storage Temperature and Duration on Levels of Selected Metabolites in Russet Burbank Seed Potatoes

ABSTRACT

Laboratory experiments were conducted in 1984 and 1985 to determine changes occurring in levels of selected metabolites in Russet Burbank seed potatoes during storage. Seed tubers were stored at 4.4°C and then warmed to either 10.0°C (1984) or 15.6°C (1985), for 0, 2, 5, and 8 weeks prior to planting. In 1984, levels of free amino acids, soluble proteins, and total, reducing, and sucrose sugars were monitored weekly. In 1985, weekly measurements were made to determine levels of phosphorylase activity, soluble proteins, and metabolic reducing activity.

Levels of total, reducing, and sucrose sugars declined with increasing storage time at 10.0°C. Conversely, both reducing and total sugar levels increased for the first four weeks, then remained constant for the remaining ten weeks at 4.4°C, while sucrose levels decreased to a low level and then increased, with random fluctuations. Phosphorylase activity remained fairly constant for four weeks regardless of storage temperatures, but then increased sharply and remained high for two weeks, after which activity decreased to initial levels and remained constant throughout the remainder of the study. This pattern may indicate a temperature-independent endogenous rhythm signaling the beginning of starch degradation in preparation for the growth of sprouts. Free amino acid content at 4.4°C or 10.0°C showed a small peak at the fourth week, steadily declined for all treatments to the ninth week, then increased continuously. Soluble protein content increased at all storage temperatures up to the fifth week, then declined slightly and remained at a constant level throughout the study. Metabolic reducing activity fluctuated at all temperatures and no distinct trends could be detected.

Among all the metabolites measured, only total and reducing sugars produced consistent trends throughout storage and showed differences in levels between treatments on the final testing date. These differences may be a reflection of physiological ageing of the seed tubers.

It appears that the temporal activation of phosphorylase may represent an endogenous signal for early starch degradation to supply energy for sprout initiation. Sustained sprout growth may require the activity of major amylolytic enzymes, such as alpha- and beta- amylase, which were not estimated in this study. The increase in phosphorylase activity followed a peak in free amino acid content and the decrease in levels of soluble proteins, indicating that a sequential ageing pattern occurred in the seed potatoes. This pattern was apparently not altered by temperatures in the range of 4.4^{o}C to 15.6^{o}C; the higher temperatures however, increased the utilization of amylolytic products, total and reducing sugars. Therefore, the levels of free amino acids, soluble proteins, phosphorylase activity, and reducing activity are not indicators of the physiological ageing in seed tubers. The lower the total or reducing sugar levels, the higher the anabolic activity, or sprouting ability. As far as tuber yield is concerned, field conditions appear to be the determining factor.

INTRODUCTION

Seed tuber health and vigor play important roles in determining crop yield. Quality factors such as the absence of disease and bruises, varietal purity, and tuber size affect seed performance (Smith, 1968). The physiological age of seed at planting also influences yield potential (Wurr, 1978). But, physiological age of a seed tuber is difficult to quantify. Ageing can be thought of "as an evolution proceeding within the tuber tissues according to a defined sequence" (Perennec amd Madec, 1960). Physiological ageing is accelerated (Perennec and Madec, 1980) and dormancy is shortened (Iritani, 1968) by increasing storage temperatures. The dormancy mechanism of potatoes is not entirely understood, although it is believed to be controlled by some unspecified balance of growth promoters and inhibitors, which are hormonal in nature (Hemberg and Larsson, 1961; Burton, 1963,1978; Bruinsma and Swart, 1970; Moorby, 1978). Certain changes in metabolic activity, metabolite levels, and enzyme systems occur in association with dormancy break.

As tuber dormancy ends, starch is broken down into sugars to supply energy demands of sprout growth and differentiation (Dimalla and Staden, 1977). It has been suggested that separate enzyme systems may be responsible for starch degradation at sprouting and changes in starch levels during dormancy (Edelman, 1963; Norton, 1963). Tests with other species suggests that increasing metabolic activity during sprouting can possibly be monitored by measuring levels of reducing activity. A relationship between levels of free amino acids and protein is quite evident during sprouting, in that protein concentrations decline and levels of free amino acids increase at sites of active growth (Emilsson and Lindblom, 1963).

This study was designed to quantify changes in levels of total, reducing, and sucrose sugars, soluble proteins, free amino acids, phosphorylase activity, and respiratory activity during storage at high and low temperatures. The possibility of using levels of these metabolites at the end of the storage period as indicators of the degree of physiological ageing will be examined.

MATERIALS AND METHODS

Treatments

Russet Burbank seed potatoes were stored at 4.4^{0}C and then warmed to either 10.0^{0}C (1984) or 15.6^{0}C (1985) for periods of 0, 2, 5, and 8 weeks prior to planting. In 1984, levels of free amino acids, soluble proteins, and total, reducing, and sucrose sugars were measured weekly for each storage regime. In 1985, phosphorylase activity, metabolic reducing activity (respiration), and soluble proteins were measured. Tests were performed at different times for seed designated for three separate planting sites and dates.

Testing Procedures

At each sampling time, two replications of five seed tubers were randomly selected from storage. In 1984, a .64 cm thick longitudinal slice of tissue was taken from the center of each tuber. In 1985, five eyes (sprouts), and the surrounding tissue were excised from each tuber. The peel was removed; approximately two grams of tissue was homogenized in 10 mls. of 50 mM 2[N-Morpholino] ethane Sulfonic acid (MES) buffer, pH 6.5, by a Polytron (Brinkmann Instruments) for 4 x 10", with 10" of cooling between each grinding. The slurry was centrifuged at 30,000 g for 10 minutes. The supernatant was filtered through a layer of glass wool and used for the following analyses. In both 1984 and 1985, soluble protein content was determined using the Coomassie Blue G-250 Assay (Bradford, 1976). In 1984, free amino acid levels were determined using a Modified Ninhydrin Method (Moore and Stein, 1954), total sugar was analyzed by the Anthrone Colorimetric Method, as described by Hodge and Hofreiter (1962), and reducing sugars were measured by Dinitrosalicylic acid Method (Bernfield, 1955). Since sucrose, fructose, and glucose have been reported as the major sugars of white potatoes (Schwimmer et al., 1954), sucrose levels were estimated by subtracting the reducing sugar from total sugar levels. In 1985, levels of phosphorylase activity were monitored using glucose-1-phosphate as substrate and soluble starch as primer. After incubation at 37.0^{o}C for 20 minutes, Pi produced was quantified by the Fiske-SubbaRow Method (Bartlett, 1959). Metabolic reducing activity (viability or respiratory activity) was determined using 2,3,5-triphenyl tetrazolium chloride (Grabe, 1970) as substrate. After 1.5 hours incubation at 35.0^{o}C, the red formazan was extracted with acetone and read at 560 nm against a reagent blank. Only the trends of change in quantity of metabolites and enzyme activities in tubers were desired, thus, results were not statistically analyzed.

RESULTS AND DISCUSSION

Total and reducing sugars decreased with increasing storage time at 10.0^{o}C (Figs. 1.1 and 1.2). These declines can probably be attributed to two processes. First of all, reducing sugar levels usually fall due to increased respiration demands associated with high temperatures (Iritani and Weller, 1977). Secondly, these seed tubers had been stored at low temperatures since harvest, and it is well documented that an actual reconditioning process occurs which converts sugars back to starch when cold stored tubers are transferred to warm storage conditions (Weaver et al., 1978). Sucrose level remained stable for the first six weeks of storage at 4.4^{o}C, declined at the seventh, then fluctuated (Fig. 1.3). Except for a few incidences, the majority of the seed tubers stored at the higher temperature had lower levels of sucrose than the tubers stored at 4.4^{o}C. Declines in sucrose levels suggest that sucrose was also probably an energy source for increased respiration and sprout growth at the end of dormancy (Dimalla and Staden, 1977; Emilsson, 1949).

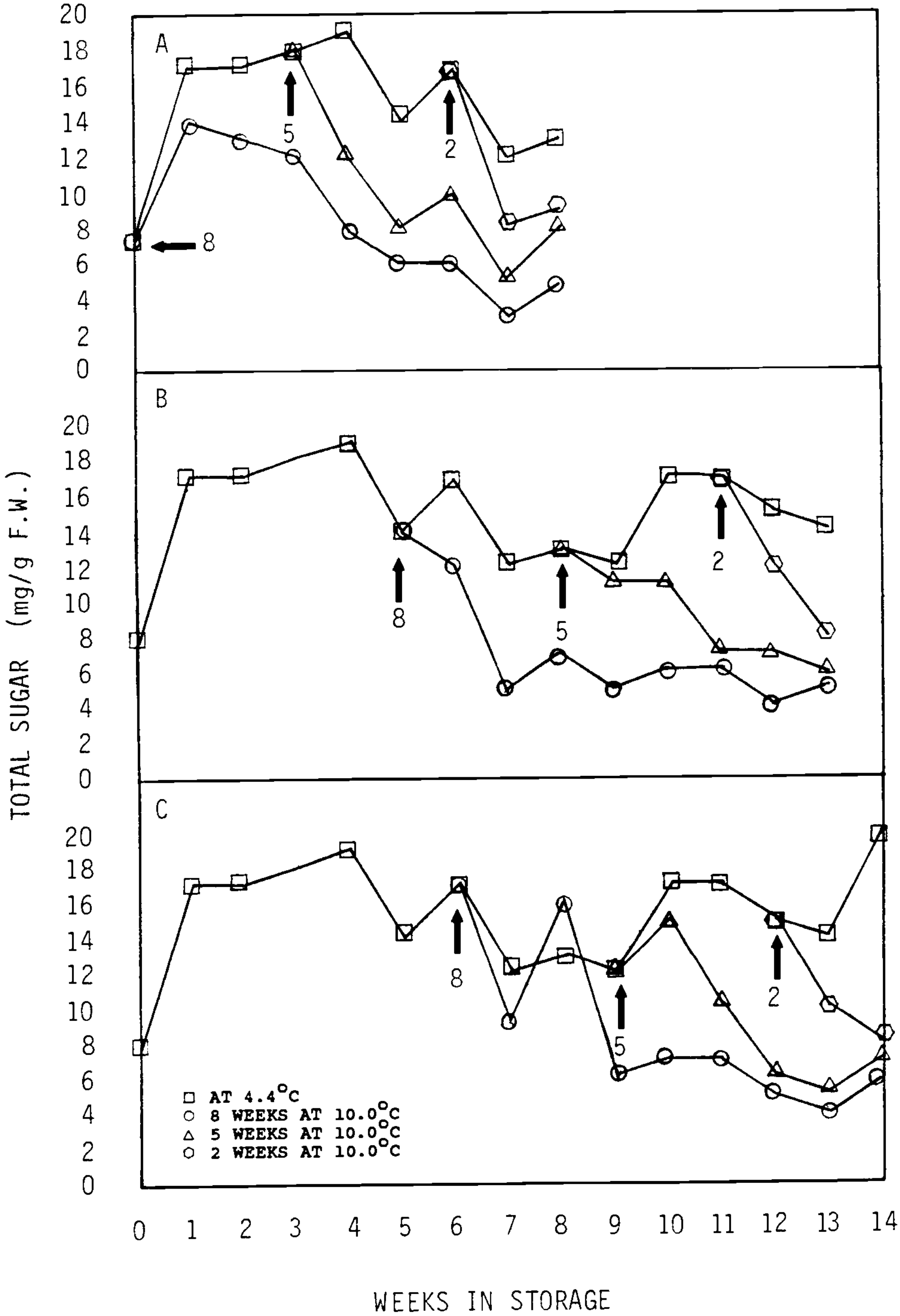
Available literature indicates that these observed changes in sugar levels due to storage temperature are consistent with other studies. At low temperatures starch is broken down, sucrose accumulates (Pollock and ap Rees, 1955), and enzymes activated by low temperatures convert sucrose to reducing sugars (Smith, 1977). Because sprout growth is minimal at 4.4^{o}C, the reducing sugar level increases within the dormant tuber. It is apparent that sugar levels are not only affected by energy demands, but also by storage temperature and storage length.

The changes in phosphorylase activities during storage were similar at 4.4^{o}C and 15.6^{o}C, indicating that phosphorylase activity probably is related to the genetic dormancy breaking process (Fig. 1.4). A dramatic increase in activity was observed at both storage temperatures five weeks after testing began. The activity remained high for two weeks and then declined to initial levels. This rapid increase in phosphorylase activity may represent an endogenous sig-

Figure 1.1 A. Effects of Storage Temperature on Total Sugar Content of Russet Burbank Seed Potatoes to be Planted at Hermiston, 1984.

Figure 1.1 B. Effects of Storage Temperature on Total Sugar Content of Russet Burbank Seed Potatoes to be Planted at Corvallis, 1984.

Figure 1.1 C. Effects of Storage Temperature on Total Sugar Content of Russet Burbank Seed Potatoes to be Planted at Powell Butte, 1984.



TOTAL SUGAR (mg/g F.W.)
WEEKS IN STORAGE
A
B
C
□ AT 4.4°C
○ 8 WEEKS AT 10.0°C
△ 5 WEEKS AT 10.0°C
⬡ 2 WEEKS AT 10.0°C

FIG. 1.1

Figure 1.2 A. Effects of Storage Temperature on Reducing Sugar Content of Russet Burbank Seed Potatoes to be Planted at Hermiston, 1984.

Figure 1.2 B. Effects of Storage Temperature on Reducing Sugar Content of Russet Burbank Seed Potatoes to be Planted at Corvallis, 1984.

Figure 1.2 C. Effects of Storage Temperature on Reducing Sugar Content of Russet Burbank Seed Potatoes to be Planted at Powell Butte, 1984.

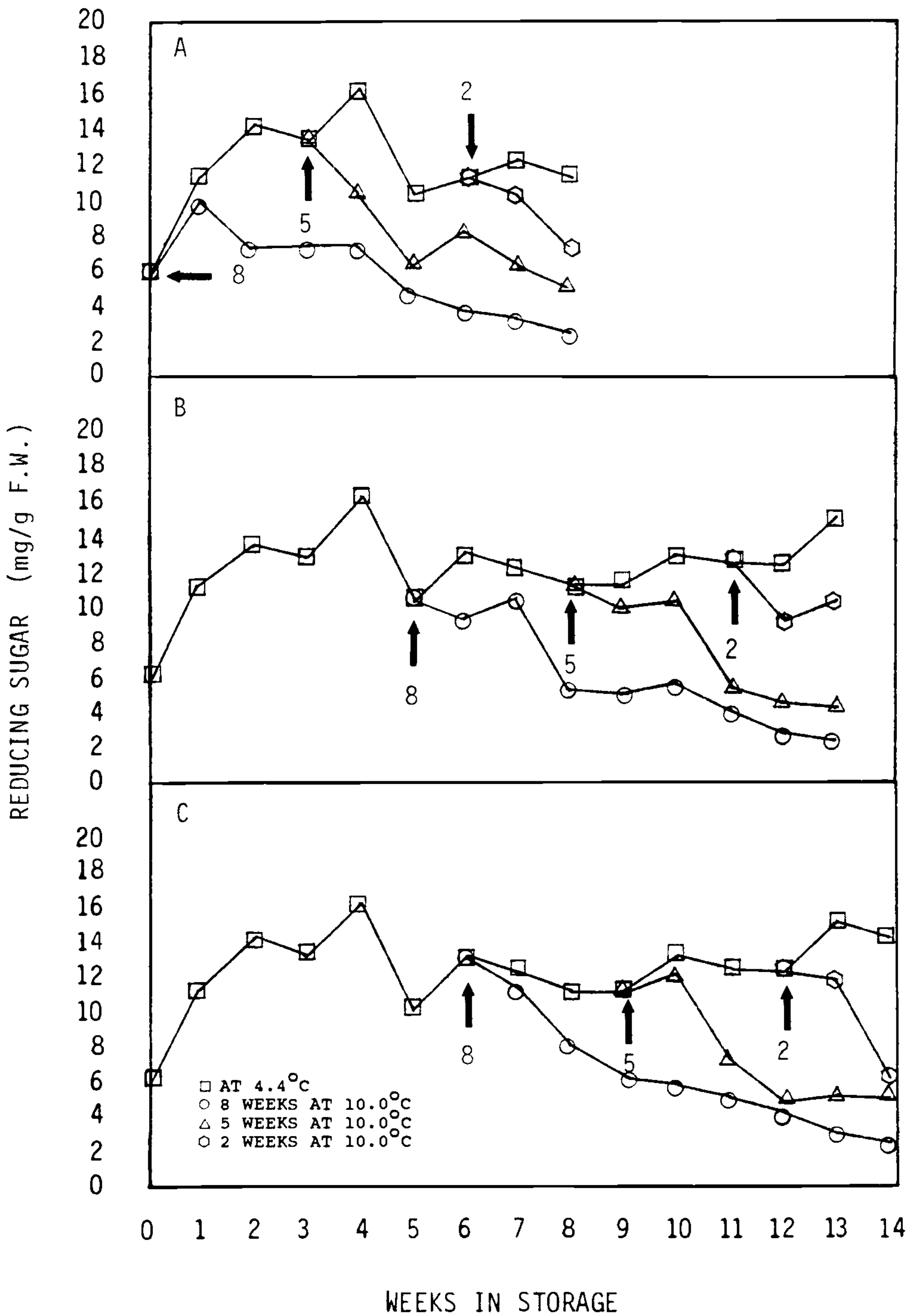

A
B
C
2
5
8
REDUCING SUGAR (mg/g F.W.)
WEEKS IN STORAGE
□ AT 4.4°C
○ 8 WEEKS AT 10.0°C
△ 5 WEEKS AT 10.0°C
⬡ 2 WEEKS AT 10.0°C

FIG. 1.2

Figure 1.3 A. Effects of Storage Temperature on Sucrose Content of Russet Burbank Seed Potatoes to be Planted at Hermiston, 1984.

Figure 1.3 B. Effects of Storage Temperature on Sucrose Content of Russet Burbank Seed Potatoes to be Planted at Corvallis, 1984.

Figure 1.3 C. Effects of Storage Temperature on Sucrose Content of Russet Burbank Seed Potatoes to be Planted at Powell Butte, 1984.

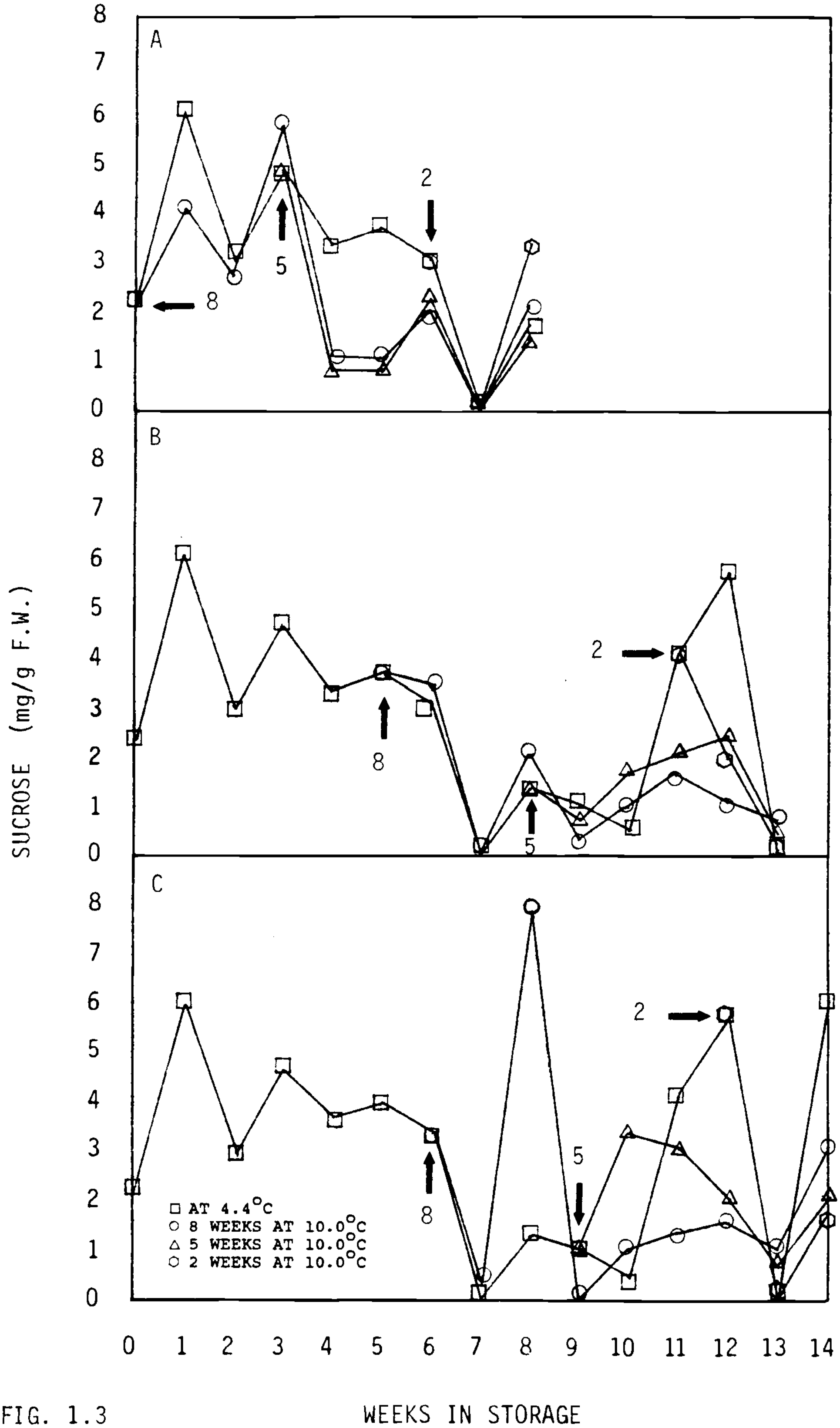

A
B
C
SUCROSE (mg/g F.W.)
0
1
2
3
4
5
6
7
8
2
5
8
□ AT 4.4°C
○ 8 WEEKS AT 10.0°C
△ 5 WEEKS AT 10.0°C
⬡ 2 WEEKS AT 10.0°C
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
WEEKS IN STORAGE

FIG. 1.3

Figure 1.4 A. Effects of Storage Temperature on Phosphorylase Activity of Russet Burbank Seed Potatoes to be Planted at Hermiston, 1985.

Figure 1.4 B. Effects of Storage Temperature on Phosphorylase Activity of Russet Burbank Seed Potatoes to be Planted at Corvallis, 1985.

Figure 1.4 C. Effects of Storage Temperature on Phosphorylase Activity of Russet Burbank Seed Potatoes to be Planted at Powell Butte, 1985.

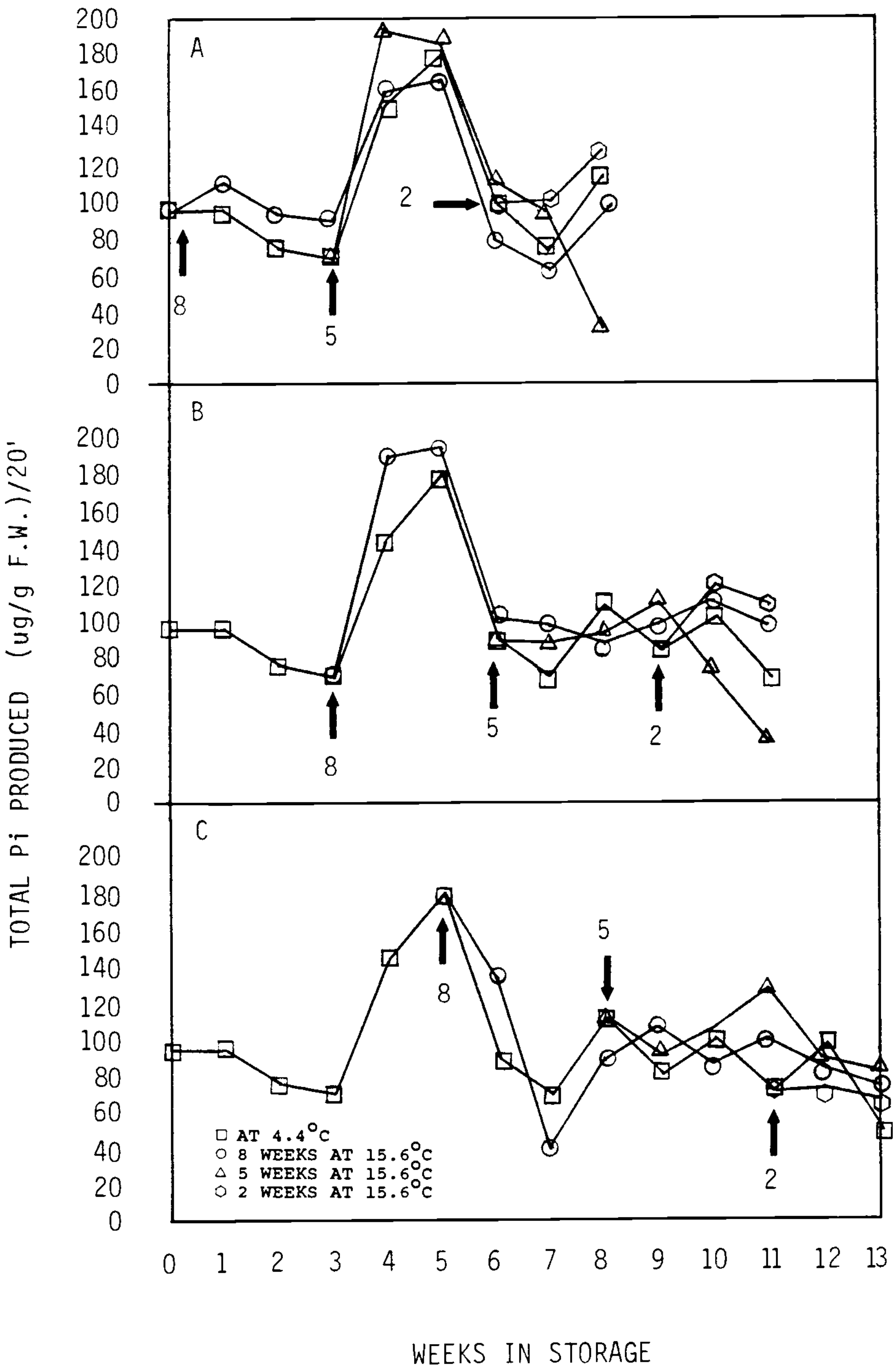

A
B
C
TOTAL Pi PRODUCED (ug/g F.W.)/20'
200
180
160
140
120
100
80
60
40
20
0
8
5
2
□ AT 4.4°C
○ 8 WEEKS AT 15.6°C
△ 5 WEEKS AT 15.6°C
⬡ 2 WEEKS AT 15.6°C
0 1 2 3 4 5 6 7 8 9 10 11 12 13
WEEKS IN STORAGE

FIG. 1.4

nal to initiate starch break down and to provide energy needs for the synthesis of other hydrolytic enzymes involved in the continuous degradation of starch. There are conflicting views in the literature as to what enzyme system is responsible for starch degradation during dormancy and sprouting, and amylase activities should be determined to clarify the results.

Free amino acid levels changed similarly during storage at 4.4^{0}C and 10.0^{0}C (Fig. 1.5). Levels began to decline four weeks after testing began, and reached a constant state approximately eleven weeks after testing. Free amino acid content then began to steadily increase throughout the remainder of the study.

Soluble protein content initially increased at both storage temperatures, and then declined slightly with increasing time in storage, until reaching a constant level (Figs. 1.6 and 1.7). This trend appeared to be more obvious in the 1985 study, in which the warm-up temperature was raised by 5.6^{0}C. A decrease in total protein levels in the seed tuber is expected upon sprout initiation and growth, but it is difficult to establish an index to determine the end of dormancy or optimal physiological ageing. The role of soluble protein needs more research to discern relationships between physiological ageing and soluble protein content.

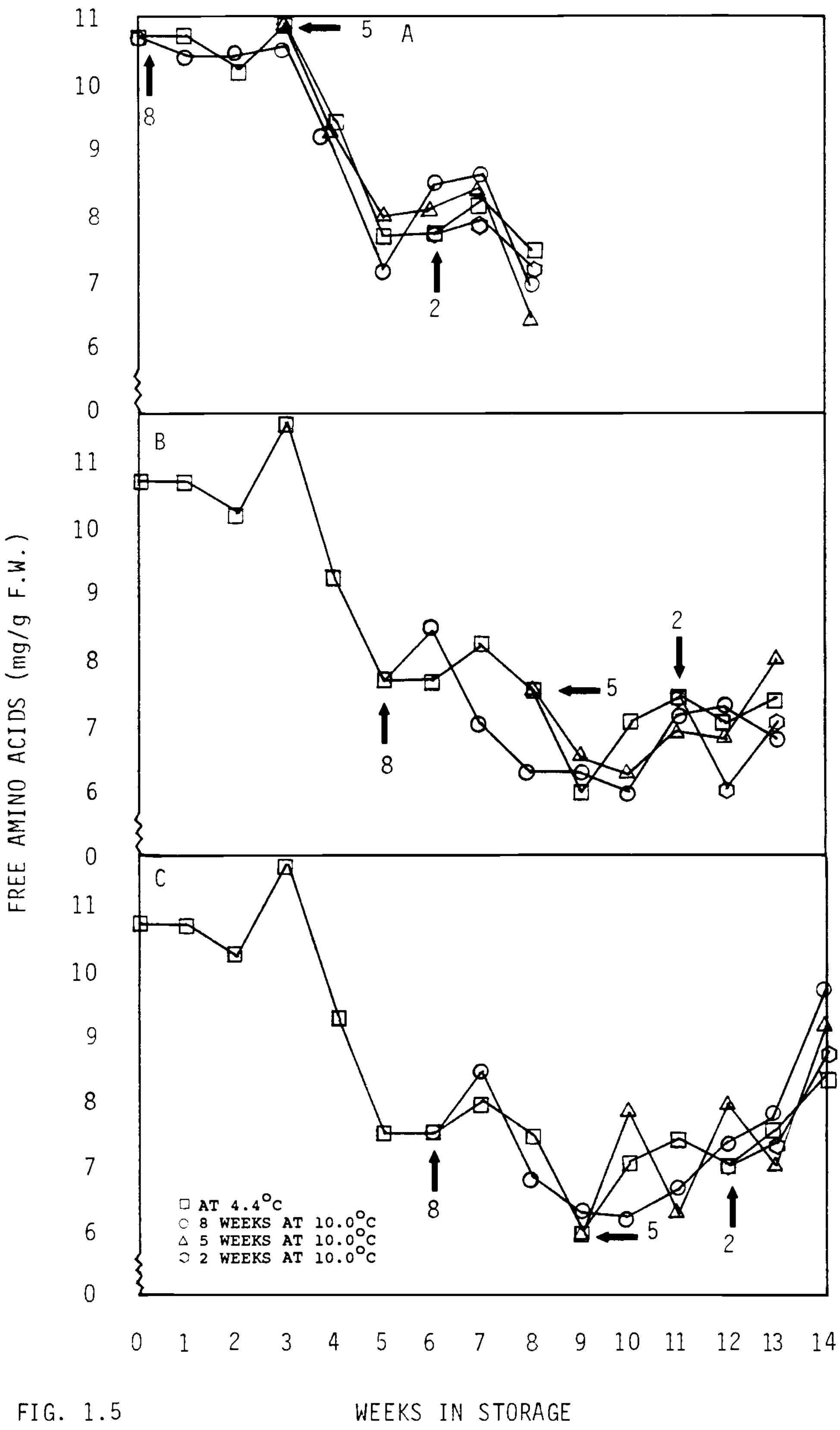
Free amino acid levels were not tested in 1985. However, in 1984 the levels of free amino acids and soluble protein show a causal relationship, in that a reduction of soluble protein at the third week of testing resulted in a simultaneous increase of amino acids. This pattern indicates that proteins are broken down and free amino acids are translocated to sites of active growth, where they are probably resynthesized into new proteins for sprout growth.

Triphenyl tetrazolium chloride tests showed little change in metabolic reducing activity throughout the storage period in the eyes of seed tubers stored at either temperature (Fig. 1.8). This lack of increase in respiratory activity as the tubers were aged by time or high storage temperature, probably was attributable to poor testing procedures and endogenous interfering substances.

Figure 1.5 A. Effects of Storage Temperature on Free Amino Acid Content of Russet Burbank Seed Potatoes to be Planted at Hermiston, 1984.

Figure 1.5 B. Effects of Storage Temperature on Free Amino Acid Content of Russet Burbank Seed Potatoes to be Planted at Corvallis, 1984.

Figure 1.5 C. Effects of Storage Temperature on Free Amino Acid Content of Russet Burbank Seed Potatoes to be Planted at Powell Butte, 1984.



A
B
C
FREE AMINO ACIDS (mg/g F.W.)
11
10
9
8
7
6
0
5
8
2
□ AT 4.4°C
○ 8 WEEKS AT 10.0°C
△ 5 WEEKS AT 10.0°C
⬡ 2 WEEKS AT 10.0°C
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14
WEEKS IN STORAGE

FIG. 1.5

Figure 1.6 A. Effects of Storage Temperature on Soluble Protein Content of Russet Burbank Seed Potatoes to be Planted at Hermiston, 1984.

Figure 1.6 B. Effects of Storage Temperature on Soluble Protein Content of Russet Burbank Seed Potatoes to be Planted at Corvallis, 1984.

Figure 1.6 C. Effects of Storage Temperature on Soluble Protein Content of Russet Burbank Seed Potatoes to be Planted at Powell Butte, 1984.

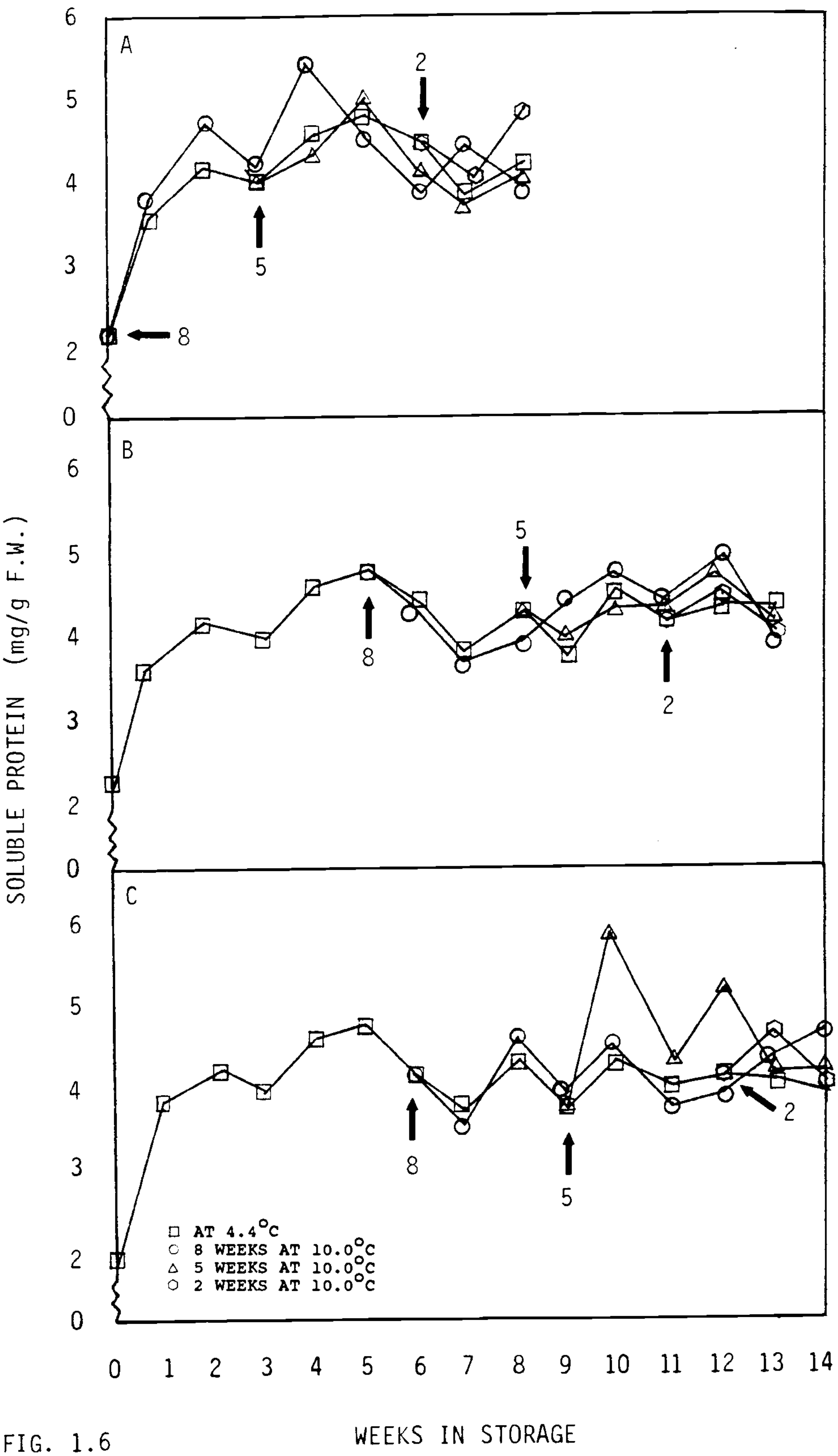
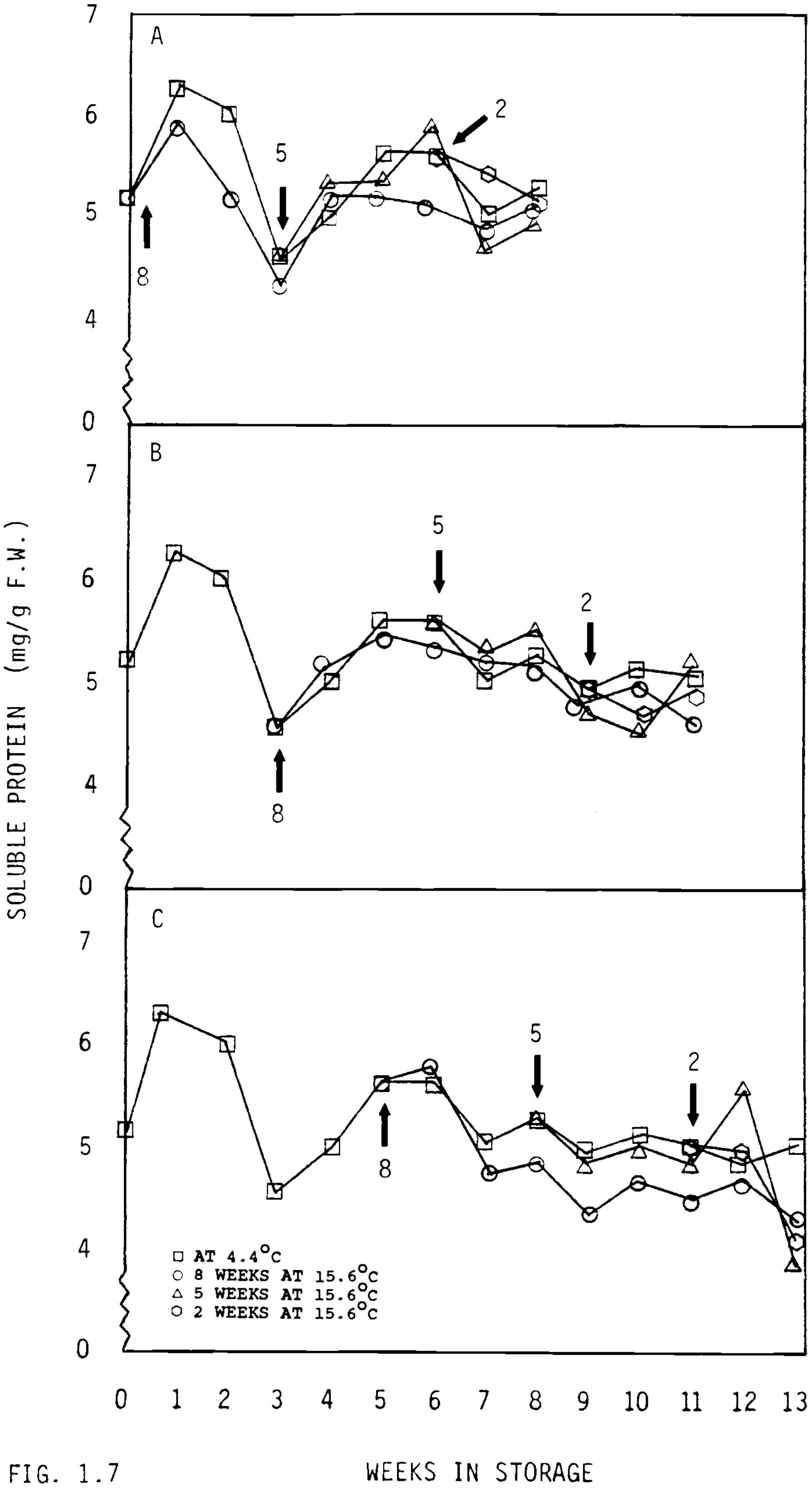

A
B
C
SOLUBLE PROTEIN (mg/g F.W.)
WEEKS IN STORAGE
□ AT 4.4°C
○ 8 WEEKS AT 10.0°C
△ 5 WEEKS AT 10.0°C
⬡ 2 WEEKS AT 10.0°C

FIG. 1.6

Figure 1.7 A. Effects of Storage Temperature on Soluble Protein Content of Russet Burbank Seed Potatoes to be Planted at Hermiston, 1985.

Figure 1.7 B. Effects of Storage Temperature on Soluble Protein Content of Russet Burbank Seed Potatoes to be Planted at Corvallis, 1985.

Figure 1.7 C. Effects of Storage Temperature on Soluble Protein Content of Russet Burbank Seed Potatoes to be Planted at Powell Butte, 1985.



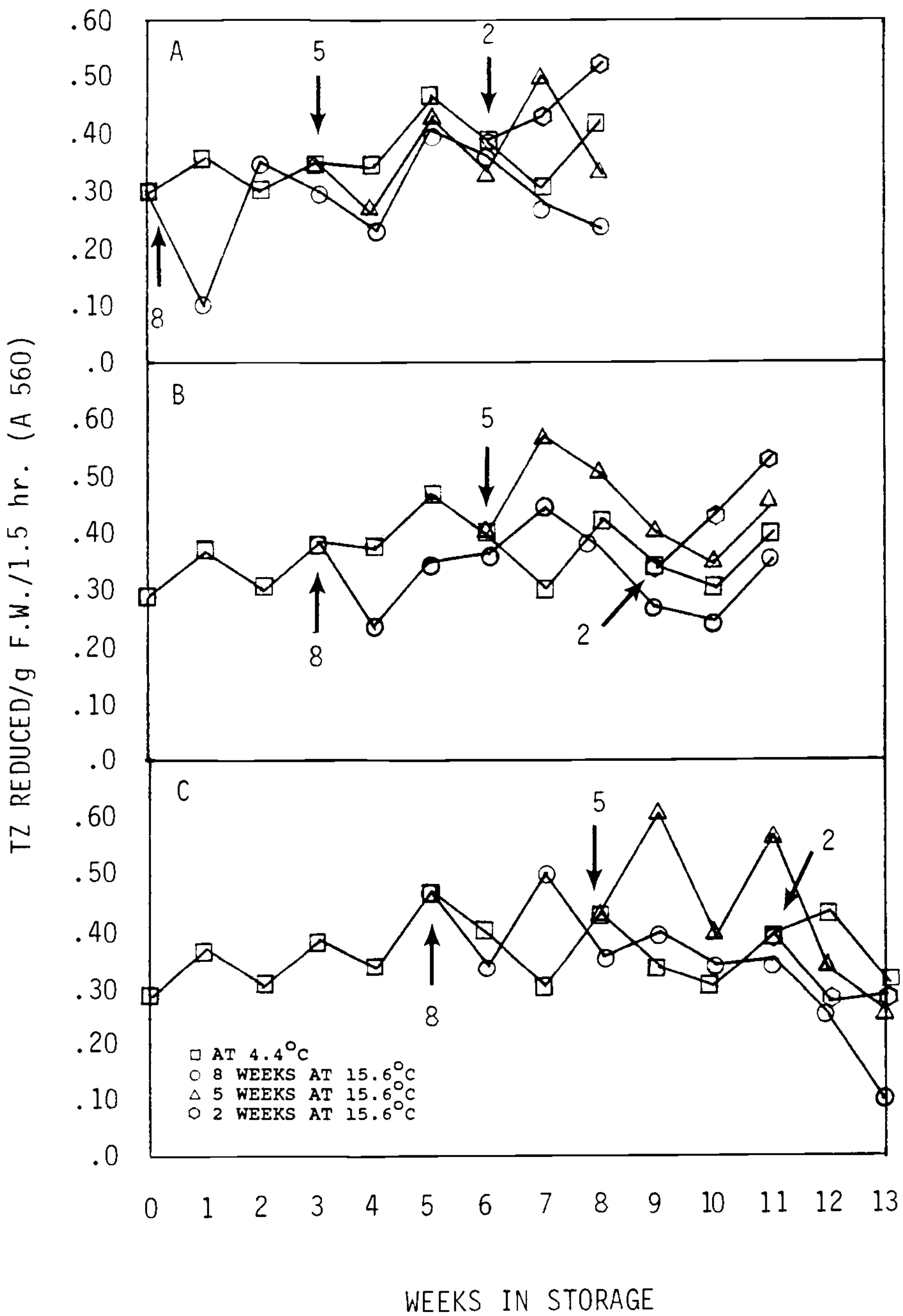
A
B
C
SOLUBLE PROTEIN (mg/g F.W.)
7
6
5
4
0
8
5
2
□ AT 4.4°C
○ 8 WEEKS AT 15.6°C
△ 5 WEEKS AT 15.6°C
○ 2 WEEKS AT 15.6°C
0 1 2 3 4 5 6 7 8 9 10 11 12 13
WEEKS IN STORAGE

FIG. 1.7

Figure 1.8 A. Effects of Storage Temperature on Respiratory Activity of Russet Burbank Seed Potatoes to be Planted at Hermiston, 1985.

Figure 1.8 B. Effects of Storage Temperature on Respiratory Activity of Russet Burbank Seed Potatoes to be Planted at Corvallis, 1985.

Figure 1.8 C. Effects of Storage Temperature on Respiratory Activity of Russet Burbank Seed Potatoes to be Planted at Powell Butte, 1985.



.60
.50
.40
.30
.20
.10
.0
A
B
C
5
2
8
TZ REDUCED/g F.W./1.5 hr. (A 560)
□ AT 4.4°C
○ 8 WEEKS AT 15.6°C
△ 5 WEEKS AT 15.6°C
⬡ 2 WEEKS AT 15.6°C
0 1 2 3 4 5 6 7 8 9 10 11 12 13
WEEKS IN STORAGE

FIG. 1.8

The removal of too much peel, and the decrease of antioxidants or reductants all may change the reducing activity of the sprouting tissue. Ascorbic acid is abundant in potato tubers, and is a good antioxidant, as is glutathione. It has been reported that ascorbic acid levels in tubers decrease as time in warm storage increases, although there are reports that conflict with these findings (Burton, 1978). Emilsson (1949) reported that glutathione content gradually decreased over time.

CONCLUSIONS

Results of tests on selected metabolites of Russet Burbank seed tubers during storage at high and low temperatures, indicate that total and reducing sugar levels consistently declined for each storage treatment, while no distinct trends in sucrose levels could be discerned for any of the treatments. Seed held continuously at 4.4^{o}C had the highest level of total and reducing sugars at planting, followed by seed held for 2, 5, and 8 weeks at 10.0^{o}C. Actual differences between levels of sugars for each treatment were small, but with more replications a standard could possibly be established for each cultivar.

Interpretations of results for the remaining metabolites were not as clear as those for the sugar fractions. It was apparent that phosphorylase activity was not greatly affected by storage temperature. The sharp increase after four weeks of storage, followed two weeks later by a temperature-independent decrease, suggests that phosphorylase activity may be influenced more by chronological age than by physiological age of the seed tuber. The activation of phosphorylase may represent a signal for initiation of starch degradation, and the major degradational enzyme would be the alpha- or beta- amylases, such as occurs in germinationg seeds (Ching, 1972).

Free amino acid content decreased slowly to a low level during the first weeks of testing, reaching a point at which levels began to climb and continue to increase with storage time. Due to similar trends at high and low storage temperatures, it would be difficult to associate changes in levels with increases in the physiological age of the seed tubers.

Changes in soluble protein content were also similar for both temperatures, with an initial increase after storage, followed by a gradual decline with increasing storage time. This trend was more pronounced for the 1985 data.

It was expected that the reducing activity of seed tubers would dramatically rise at the higher storage temperature, as metabolic activity and respiration increased with sprouting. However, no definite trends in reducing activity could be detected for the various storage regimes. The lack of increase in activity may be caused by endogenous interfering substances preventing TZ reduction, or the loss of meristematic sites during tissue preparation.

As seed tubers age physiologically and chronologically in storage, a series of biochemical changes occur that lead to breaking of dormancy and the initiation of sprout growth and development. It is difficult to separate changes that result from the process from those that contribute to it. It is interesting to note that immediately after the phosphorylase activity increased, soluble proteins began to decrease, and free amino acid content began to increase. Perhaps phosphorylase is the triggering enzyme that initiates the mobilization of starch reserves and the break down of soluble protein to free amino acids for sprout growth.

The metabolic process of dormancy break is complex and it is perhaps not necessary to understand triggering mechanisms, but instead to be able to use measureable levels of metabolites and enzyme activity to represent the status of the process. The ability to use levels of metabolites and certain enzymes as criteria to quantify physiological age may not be possible, however. The lack of differences in levels at planting and inconsistent trends throughout this study suggest that it would be difficult to rely on test levels to correctly quantify the true physiological status of the seed. Results hint that it may be possible to use levels of reducing and total sugars to indirectly quantify the degree of physiological ageing that a seed tuber has undergone. However, because of the strong influence of temperature on sugar levels, previous storage history starting from harvest would be required. It may be possible to predict seed performance by testing sugar levels, once the correct temperature regime and physiological age is established for optimum yields.

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CH II

Effects of Seed Tuber Conditioning on Growth and Development of Russet Burbank Potatoes

ABSTRACT

Field experiments were conducted in 1984 and 1985 at three locations in Oregon to study the effects of seed storage temperature and duration on sprout development, plant stands, emergence rates, plant growth and vigor, senescence rates, time of tuber set, and stem development. In 1984, seed was stored at 4.4^{o}C and was warmed to 10.0^{o}C for 0, 2, 5, and 8 weeks prior to planting. In 1985, treatments were identical, except seed was warmed to 15.6^{o}C.

As time in storage at the elevated temperatures increased so did sprout length and the degree of apical dominance, as indicated by the fact that warm storage resulted in seed tubers with sprouts emerging predominately from the apical postion. Numbers of sprouts per tuber did not differ greatly among treatments; however, sprout growth was minimal at 4.4^{o}C.

Seed warmed for 5 and 8 weeks at 10.0^{o}C and 15.6^{o}C produced plants which generally emerged earlier and showed greater early season growth than the 2 and 0 week treatments. The presence of sprouts at planting apparently resulted in rapid emergence and early growth. Plant stands were similar for all treatments. Early differences in growth rate diminished rapidly as the season progressed, and no differences in time of tuber set or vine senescence could be detected among treatments. Numbers of aboveground stems per hill consistently increased as time in storage at 10.0^{o}C and 15.6^{o}C increased. Large numbers of stems from warmed seed may be due to lessened apical dominance after planting, secondary stem development, and sprout damage at planting.

INTRODUCTION

Seed potato quality at planting influences plant growth and development and ultimately affects crop yield. Several researchers (Susnoschi, 1974,1981ab; Susnoschi et al., 1976; Iritani, 1968; Iritani et al., 1983; Toosey, 1963) have proposed that the physiological age of seed at planting be considered a characteristic of seed quality. Seed which shows sprout growth at planting is defined as being physiologically older than seed showing little or no sprout growth (Perrenec and Madec, 1960; Kawakami, 1962,1963; Krijthe, 1962; Toosey, 1964). The physiological ageing process can be accelerated by exposing seed to elevated storage temperatures prior to planting (Perrenec and Madec, 1980).

Manipulating the physiological age of seed potatoes in this fashion affects the degree of tuber apical dominance and morphology, size, number, and growth rate of the sprouts (Headford, 1962). Generally, seed with highly developed sprouts produces plants which emerge faster, set tubers earlier, have a lower bulking rate, senesce earlier (Wurr, 1978; Iritani, 1967,1968; Fischnich and Krug, 1963; Rozier-Vinot, 1971; Toosey, 1964; Davidson, 1958; Hartman, 1934), and produce a higher number of aboveground stems, (Allen, 1978; Perrenec and Madec, 1980; Smith, 1937) than plants from tubers without sprouts at planting. Seed stored continuously at low temperatures tend to produce few stems (Iritani, 1968).

Conditioning seed prior to planting by manipulating storage temperatures may allow the grower to tailor seed for optimum yields in any given production area. Iritani (1967; et al., 1983) and Toosey (1964) determined that tuber size is inversely proportional to the number of tubers in a hill. The number of tubers per stem is usually constant (Bates, 1936); therefore as stem number increases, tuber size decreases due to competition for substrates. Growers may take advantage of seed conditioning to control plant growth and stem number, and thus yield quantity and quality.

MATERIALS AND METHODS

Climatic Characteristics of Study Sites

Field experiments were conducted in (1984 and 1985) at three sites in Oregon. Crops were grown using cultural and pest control methods practiced by local growers.

Site 1 was located on the Columbia Basin Agricultural Research Center at Hermiston, in the Umatilla Drainage Basin. The climate is mild with 160-190 frost-free days. The average annual temperature is 10.6^{0}C-11.7^{0}C, with an annual precipitation of 17.8 cm-22.9 cm. Days are generally hot and the nights cool during the growing season, and light intensity is high. The elevation ranges from 80.8 M-213.5 M. The Columbia Basin Lowlands are made up of the Winchester soil series. Soils are loose, deep, coarse textured, well drained, formed in wind blown sand, and are neutral to slightly alkaline. Average yields with Russet Burbank exceed 56 t/ha.

Site 2 was situated on the Oregon State University Vegetable Crops Farm at Corvallis in the Willamette Drainage Basin. The climate is cool and temperate, with warm dry summers and cool wet winters and more than 200 frost-free days. The growing season is not overly long however, due to cool, wet, Spring weather. The average annual temperature is 10.6^{0}C-12.2^{0}C, with an annual precipitation of 101.6 cm. The elevation is around 122 M. Bellpine, Dixonville, and Firgrell soils can be found in Benton County. Soils are clayey and can have loam surface layers. They are moderate to well drained and slight to strongly acidic. Yields average about 45 t/ha with Russet Burbank.

Site 3 was located on the Central Oregon Experiment Station at Powell Butte, in the Deschutes Drainage Basin. Most of the region is semiarid, with dry summers and moist winters, and has a 70-100 day growing season. The average annual temperature ranges from 7.8^{0}C-8.9^{0}C, with an annual precipitation of 20.3 cm-30.5 cm. The elevation ranges from 854 M-1525 M. The Deschutes soils are moderately deep, moderately coarse textured, well drained, and formed mostly from pumice. Average yields with Russet Burbank are about 40 t/ha.

Treatments

1984 - Certified Russet Burbank seed potatoes were placed in storage at 4.4^{o}C on Jan. 2 prior to the beginning of the experiment. Seed had been stored at approximately 4.4^{o}C before purchase. Seed potatoes were randomly selected from the 4.4^{o}C storage and placed in a cooler at 10.0^{o}C for 0, 2, 5, and 8 weeks prior to planting on April 12 (Hermiston), May 17 (Corvallis), and May 23 (Powell Butte).

1985 - Russet Burbank seed potatoes which had been held at approximately 4.4^{o}C on a Central Oregon farm were placed in storage at 4.4^{o}C on Dec. 28, 1984 prior to the beginning of the experiment. Seed potatoes were randomly selected at appropriate times and warmed at 15.6^{o}C for 0, 2, 5, and 8 weeks prior to planting on April 16 (Hermiston), May 15 (Corvallis), and May 21 (Powell Butte). Because of the higher warm-up temperature in 1985, temperature and relative humidity were recorded weekly in both the 4.4^{o}C and 15.6^{o}C storages. Relative humidity was recorded with a fan driven psychrometer, model KSIC 27AM460. In the 15.6^{o}C storage, burlap sacks partially immersed in basins of water were hung from the ceiling to increase the humidity. The average relative humidity in the 15.6^{o}C storage was 83% and never dropped below 80%.

Measurement of Seed and Plant Characteristics

1984-1985. Prior to planting, 25 tubers were randomly selected from each treatment and average sprout length, sprout number, and degree of apical dominance were recorded. Plant stand was recorded approximately 45 days after planting for all replications and rate of emergence was recorded as the number of days between planting and 50 % plant emergence. Plant vigor was rated visually on a scale of 1 to 5, 1 being less vigorous than 5. Numbers of aboveground stems were recorded at mid-season. Plant vigor throughout the season, tuber set, and time of senescence were subjectively evaluated.

Seed Preparation and Planting Method

All seed were warmed to room temperature prior to being cut into seed pieces weighing approximately 56.7 g. Seed pieces prepared for Corvallis and Powell Butte were treated with Manzeb, fungicide dust. Seed pieces were mechanically planted nine inches apart in rows 34" wide and 25 feet long. Border rows were planted on each side of the experiment. In 1984 seed was planted on April 12 (Hermiston), May 17 (Corvallis), and May 23 (Powell Butte), and in 1985, on April 16 (Hermiston), May 15 (Corvallis), and May 21 (Powell Butte). Seed was planted using an assisted feed type planter. Some large sprouts were unavoidably broken off during cutting and planting.

Experimental Design

A randomized complete block design was used in all tests. Treatments were replicated four times in 1984 and six times in 1985.

Cultural Practices

Site 1, Hermiston. In 1984, fertilizer was broadcast pre-plant at a kg/ha rate of 56N (nitrogen) $84P_2O_5$ (phosphate) 112 k_2O (potassium) 11.2ZN (zinc) and 2.2B (boron). At planting additional fertilizer was banded at a kg/ha rate of $56N-84P_2O_5-112K_2O-78.4S$ (sulfur). Beginning May 30 thru July 27, N was applied once a week at a kg/ha rate of 28 to 44. A total of 69.6 cm of water was used during the season. Weeds were controlled with applications of EPTC (3.9 kg/ha) and Metribuzin (.56 kg/ha). Insects were controlled with applications of Fonofos (4.4 kg/ha), Aldicarb (3.4 kg/ha), and

Methamidophos (1.1 kg/ha). Vines were sprayed with Dinoseb on Sept. 12. Cultural practices used in 1985, were similar to the above; however, fertilizer was banded at planting at kg/ha rate of 89.6N-156.8P_2O_5-72.8S. Beginning June 4 thru July 17, N was applied once a week at a kg/ha rate of 33.6 to 56. A total of 73.4 cm of water was sprinkler-applied during the season. Fluazifop-butyl was added to control annual grasses, and Phosmet (4.5 kg/ha) was added for insect control. Dinoseb was applied to the vines on Sept. 23.

Site 2, Corvallis. Plots were fertilized in 1984 with 15N-158P_2O_5-15K_2O broadcast and incorporated before planting at a rate of 560 kg/ha and 16N-16P_2O_5-16K_2O banded at planting at 1,120 kg/ha. Approximately 50.8 cm of water was sprinkler-applied during the season. Metribuzin and Glyphosate were used to control weeds. Fonofos was used prior to planting, and Aldicarb was applied at planting for insect control. Manzeb and Metalaxyl were applied in alternating weekly rotations to control late and early blight. Vines were sprayed with Dinoseb on Sept. 18. Pest control measures in 1985 were similar to those used in 1984, the only exception being that Aldicarb was not applied at planting. Vines were sprayed with diesel oil and dinitro on Sept. 19. All other cultural practices were the same as those used in 1984.

Site 3, Powell Butte. In 1984, 16N-16P_2O_5-16K_2O fertilizer was banded at planting at a rate of 1,120 kg/ha. Approximately 42.7 cm of water was applied during the growing season. Weeds were controlled by 6.4 litres/ha of EPTC applied prior to planting. Methamidophos was applied during the season to control insects. Vines were sprayed with Dinoseb on Sept. 21 at a rate of 4.7 litres/ha. Identical cultural practices were used in 1985.

Statistical Analysis

Data were statistically analysed using an Analysis of Variance (ANOVA) program created for the IBM Personal Computer by the O.S.U. Crop Science Department in 1984.

RESULTS AND DISCUSSION

Sprout growth was clearly influenced by seed storage temperature and duration. Apical dominance increased with increasing time in storage at $10.0^{o}C$ and $15.6^{o}C$, as did sprout length (Tables 2.1 to 2.6). Sprouts/seed tuber did not differ greatly among treatments, but as time at the elevated temperatures increased, sprouts emerged predominately from the apical (bud) end of the seed tuber. Sprout growth was minimal with continuous $4.4^{o}C$ storage. These results support reports by several researchers (Moorby, 1978; Allen, 1978; Susnoschi, 1981a; Headford, 1962).

The 1984 Corvallis trial showed no obvious treatment effects on percent plant stand; however, plants from seed warmed to $10.0^{o}C$ for 5 and 8 weeks did emerge early and appeared more vigorous early in the season than plants from the other treatments (Table 2.7). Differences in plant vigor diminished as the season progressed and no difference in rates of tuber set or plant senescence could be detected among treatments. Aboveground stem numbers per hill did not differ statistically at the .05 level (Table 2.7), but stem numbers did increase with time in $10.0^{o}C$ storage (Fig. 2.1 A).

Powell Butte data for 1984 showed that seed warmed to $10.0^{o}C$ for 5 and 8 weeks produced significantly more aboveground stems than seed warmed for only 2 weeks (Fig. 2.1 B and Table 2.8). Percent plant stand and early plant vigor were similar for all treatments (Table 2.8). Rate of tuber set and plant senescence were also similar for all treatments.

At Hermiston in 1985, seed stored continuously at $4.4^{o}C$ had a slightly lower percent plant stand than all other treatments (Table 2.9). Aboveground stem numbers per hill did not differ statistically at the .05 level (Table 2.9) but, numbers of stems per hill consistently increased with increasing time at $15.6^{o}C$ (Fig. 2.2 A).

The Corvallis trial in 1985 showed seed warmed at $15.6^{o}C$ for 8 weeks produced significantly more stems than seed warmed for 0 and 2 weeks (Fig. 2.2 B and Table 2.10), and seed warmed at $15.6^{o}C$ for 5 weeks produced significantly more stems per hill than seed warmed

Table 2.1. Effects of Storage Temperature on Sprouting Characteristics of Russet Burbank Seed Potatoes. Hermiston, 1984.

Weeks at[1/] 10.0°C	Sprouts/ tuber	Avg. sprout length, cm	Apical dominance
0	.0	<.10	none
2	2.36	.20	none
5	1.76	2.50	strong
8	2.48	4.13	moderate

[1/] Seed held at 4.4°C prior to conditioning at 10.0°C. Data taken at end of storage regime.

Table 2.2 Effects of Storage Temperature on Sprouting Characteristics of Russet Burbank Seed Potatoes. Corvallis, 1984.

Weeks at[1/] 10.0°C	Sprouts/ tuber	Avg. sprout length, cm	Apical dominance
0	.0	<.10	none
2	2.03	.22	weak
5	1.80	2.44	moderate
8	2.11	5.76	moderate

[1/] Seed held at 4.4°C prior to conditioning at 10.0°C. Data taken at end of storage regime.

Table 2.3. Effects of Storage Temperature on Sprouting Characteristics of Russet Burbank Seed Potatoes. Powell Butte, 1984.

Weeks at[1/] 10.0°C	Sprouts/ tuber	Avg. sprout length, cm	Apical dominance
0	.0	<.10	none
2	1.78	.25	weak
5	1.72	2.75	moderate
8	1.84	7.20	moderate

[1/] Seed held at 4.4°C prior to conditioning at 10.0°C. Data taken at end of storage regime.

Table 2.4. Effects of Storage Temperature on Sprouting Characteristics of Russet Burbank Seed Potatoes. Hermiston, 1985.

Weeks at[1/] 15.6°C	Sprouts/ tuber	Avg. sprout length, cm	Apical dominance
0	1.50	.10	weak
2	1.30	2.8	weak
5	1.20	7.8	moderate
8	1.00	16.3	strong

[1/] Seed held at 4.4°C prior to conditioning at 15.6°C. Data taken at end of storage regime.

Table 2.5. Effects of Storage Temperature on Sprouting Characteristics of Russet Burbank Seed Potatoes. Corvallis, 1985.

Weeks at[1/] 15.6°C	Sprouts/ tuber	Avg. sprout length, cm	Apical dominance
0	1.52	.20	weak
2	1.31	3.0	moderate
5	1.34	11.0	strong
8	1.03	17.9	moderate

[1/] Seed held at 4.4°C prior to conditioning at 15.6°C. Data taken at end of storage regime.

Table 2.6. Effects of Storage Temperature on Sprouting Characteristics of Russet Burbank Seed Potatoes. Powell Butte, 1985.

Weeks at[1/] 15.6°C	Sprouts/ tuber	Avg. sprout length, cm	Apical dominance
0	1.80	.20	weak
2	1.82	.90	moderate
5	1.36	6.1	moderate
8	1.23	14.6	strong

[1/] Seed held at 4.4°C prior to conditioning at 15.6°C. Data taken at end of storage regime.

Table 2.7. Effects of Seed Storage on Growth and Development of Russet Burbank Plants. Corvallis, 1984.

Weeks at[1/] 10.0°C	Days to 50% emergence	%[2/] stand	Plant[3/] vigor	Stems/[4/] hill
0	30	90	3	3.28
2	30	95	3	3.15
5	21	92	4	3.35
8	21	93	4	3.70
LSD, .05	-	-	-	NS

[1/] Seed held at 4.4°C prior to conditioning at 10.0°C.

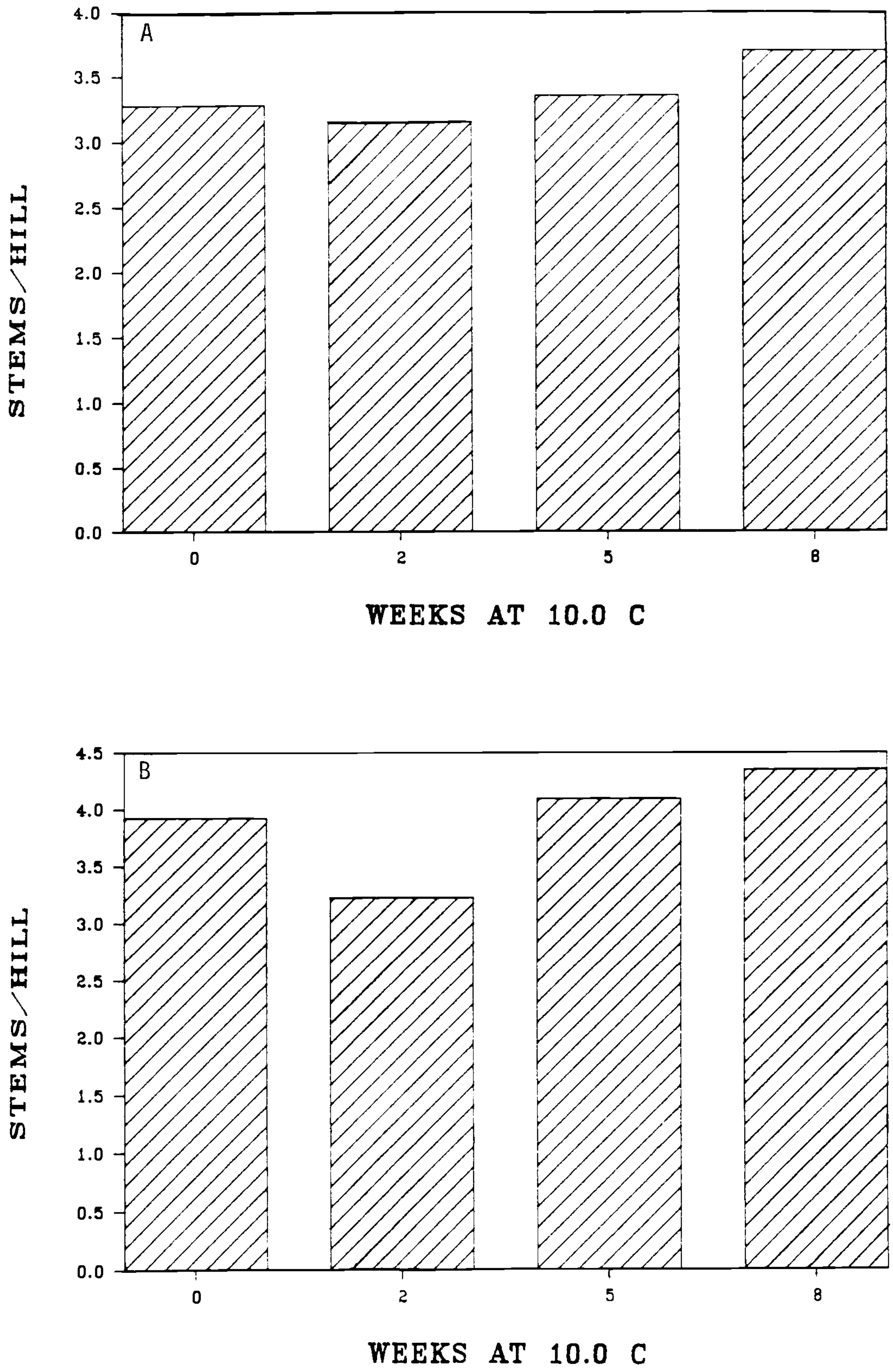
[2/] Counted approximately 45 days after planting.

[3/] Rated after 50% emergence on a scale of 1-5, 1 being less vigorous than 5.

[4/] Stems at soil level, counted at midseason.

Figure 2.1 A. Effects of Seed Storage on Aboveground Stem Numbers of Russet Burbank Plants at Midseason. Corvallis, 1984.

Figure 2.1 B. Effects of Seed Storage on Aboveground Stem Numbers of Russet Burbank Plants at Midseason. Powell Butte, 1984.



A
STEMS/HILL
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
0
2
5
8
WEEKS AT 10.0 C
B
STEMS/HILL
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
0
2
5
8
WEEKS AT 10.0 C

FIG. 2.1

Table 2.8. Effects of Seed Storage on Growth and Development of Russet Burbank Plants. Powell Butte, 1984.

Weeks at[1/] 10.0°C	%[2/] stand	Plant[3/] vigor	Stems/[4/] hill
0	86	4	3.93
2	89	4	3.23
5	91	4	4.10
8	89	4	4.35
LSD, .05	-	-	.78
LSD, .01	-	-	1.12

[1/] Seed held at 4.4°C prior to conditioning at 10.0°C.

[2/] Counted approximately 45 days after planting.

[3/] Rated after 50% emergence on a scale of 1-5, 1 being less vigorous than 5.

[4/] Stems at soil level, counted at midseason.

Table 2.9. Effects of Seed Storage on Growth and Development of Russet Burbank Plants. Hermiston, 1985.

Weeks at[1/] 15.5°C	%[2/] stand	Stems/[3/] hill
0	91	2.07
2	95	2.04
5	95	2.17
8	95	2.44
LSD, .05	-	NS

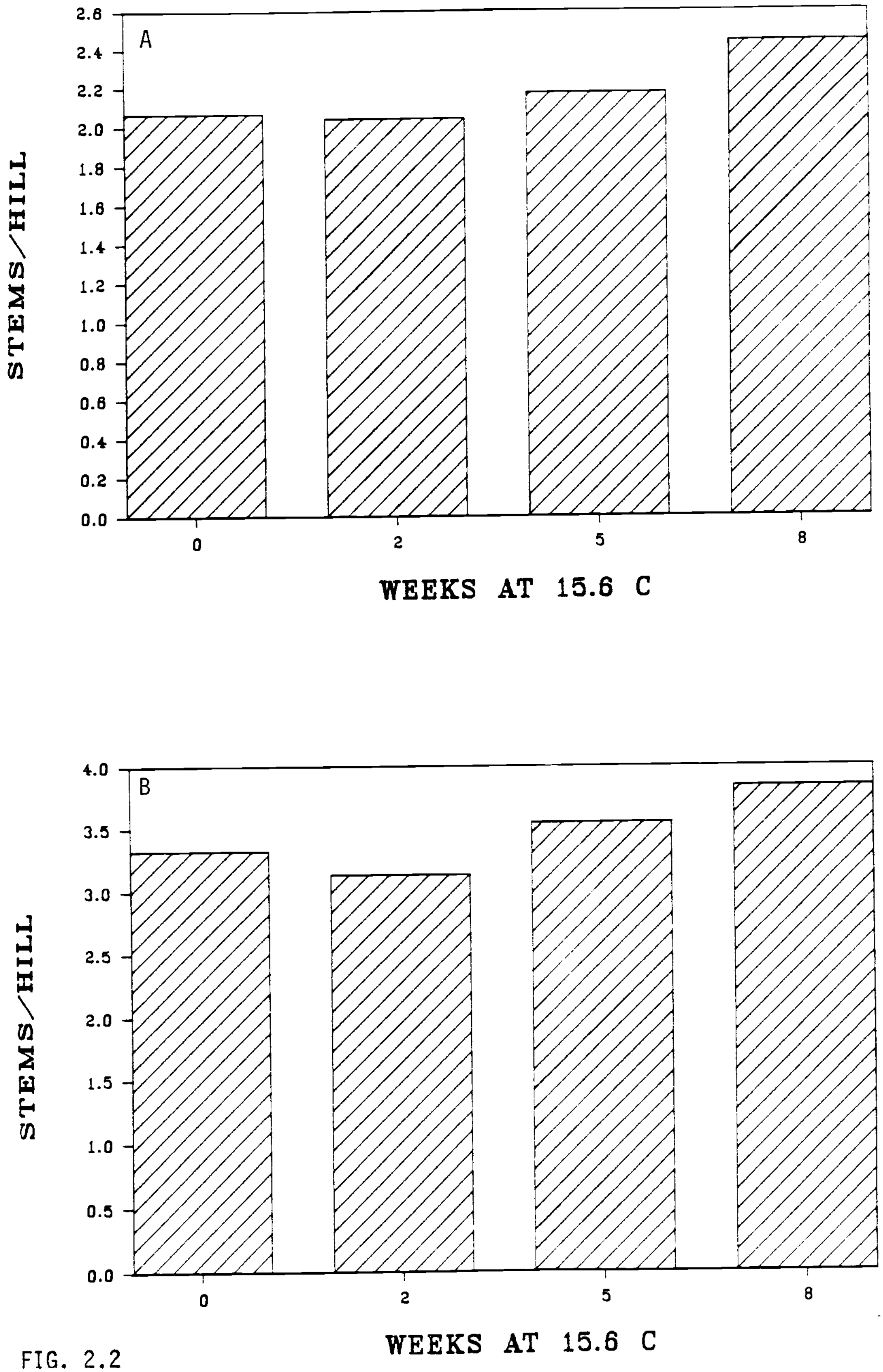
[1/] Seed held at 4.4°C prior to conditioning at 15.6°C.

[2/] Counted at end of season.

[3/] Stems at soil level, counted at end of season.

Figure 2.2 A. Effects of Seed Storage on Aboveground Stem Numbers of Russet Burbank Plants at End of Season. Hermiston, 1985.

Figure 2.2 B. Effects of Seed Storage on Aboveground Stem Numbers of Russet Burbank Plants at Midseason. Corvallis, 1985.



A
STEMS/HILL
2.6
2.4
2.2
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
0
2
5
8
WEEKS AT 15.6 C
B
STEMS/HILL
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
0
2
5
8
WEEKS AT 15.6 C

FIG. 2.2

Table 2.10. Effects of Seed Storage on Growth and Development of Russet Burbank Plants. Corvallis, 1985.

Weeks at[1/] 15.6°C	Days to 50% emergence	%[2/] stand	Plant[3/] vigor	Stems/[4/] hill
0	15	97	3	3.32
2	17	94	4	3.14
5	10	94	5	3.56
8	12	91	4	3.84
LSD, .05	-	-	-	.36
LSD, .01	-	-	-	.49

[1/] Seed held at 4.4°C prior to conditioning at 15.6°C.

[2/] Counted approximately 45 days after planting.

[3/] Rated after 50% emergence on a scale of 1-5, 1 being less vigorous than 5.

[4/] Stems at soil level, counted at midseason.

at 15.6^{o}C for 2 weeks (Fig. 2.2 B and Table 2.10). Seed warmed for 5 and 8 weeks at 15.6^{o}C produced plants which emerged early and were vigorous early in the season (Table 2.10). By midseason, differences in plant vigor had diminished, and no treatment effects on time of tuber set or senescence rates were noted.

Powell Butte tests in 1985 showed similar plant stands for all treatments (Table 2.11). Seed warmed for 5 and 8 weeks at 15.6^{o}C emerged slightly earlier than the other treatments; however, plants from the 2 and 5 week treatment seemed more vigorous than those from the plants produced from seed warmed for 0 and 8 weeks (Table 2.11). No differences in midseason plant vigor, time of tuber set, or senescence rates were noted among treatments. Seed warmed at 15.6^{o}C for 5 and 8 weeks produced significantly more stems per hill than seed warmed for only 0 and 2 weeks (Table 2.11 and Fig. 2.3).

Warming seed at 10.0^{o}C and 15.6^{o}C for 5 and 8 weeks generally favored early emergence and increased early-season plant growth. These results support other reports (Wurr, 1978; Iritani, 1967,1968; Toosey, 1962,1963; Fischnich and Krug, 1963; Rozier-Vinot, 1971). Toosey (1964) reported reduced vigor later in the season for plants originating from seed conditioned at warm storage temperatures. This was not noted in this study, however, differences in foliage later in the season may have been too subtle to distinguish visually. It is possible that field conditions and climate interacted to mask treatment effects related to foliage vigor, tuber initiation, and senescence rates. As time in storage at 10.0^{o}C and 16.6^{o}C increased, the aboveground stem number per hill produced by this conditioned seed also increased. These results coincide with previous reports that state as sprout development in storage increases, so does stem number per hill (Perennec and Madec, 1980; Iritani et al., 1983; Kawakami, 1962,1963).

Table 2.11. Effects of Seed Storage on Growth and Development of Russet Burbank Plants. Powell Butte, 1985.

Weeks at 15.6°C [1/]	Days to 50% emergence	% stand [2/]	Plant vigor [3/]	Stems/hill [4/]
0	24	91	3	3.62
2	24	91	5	3.56
5	17	94	5	4.42
8	17	91	4	4.75
LSD, .05	-	-	-	.44
LSD, .01	-	-	-	.61

[1/] Seed held at 4.4°C prior to conditioning at 15.6°C.

[2/] Counted approximately 45 days after planting.

[3/] Rated after 50% emergence on a scale of 1-5, 1 being less vigorous than 5.

[4/] Stems at soil level, counted at midseason.

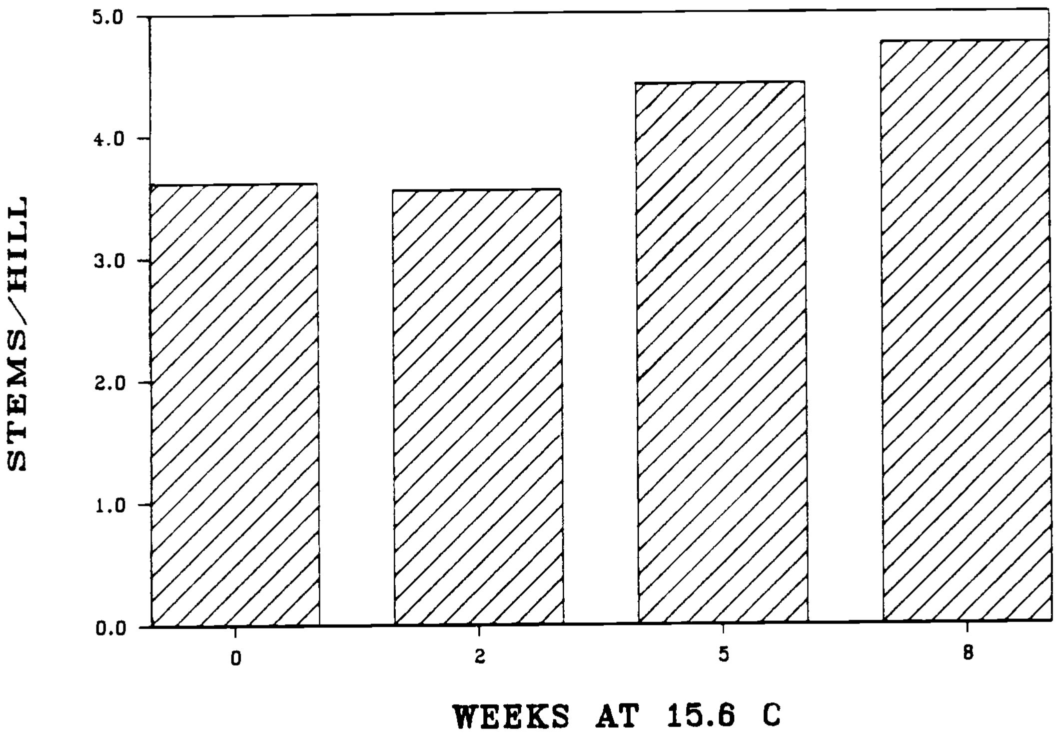


FIG. 2.3 Effects of storage temperature on aboveground stem numbers of Russet Burbank plants at midseason. Powell Butte. 1985.

CONCLUSIONS

The absence of any large treatment effects on plant stands indicates that seed conditioned at elevated temperatures is not inferior to seed stored at low temperatures in terms of germinability. The early emergence and greater early season plant growth associated with seed warmed at 10.0^{o}C and 15.6^{o}C apparently hastened the onset of the vegetative period, due to the high degree of sprout development at planting (Toosey, 1963). Toosey (1964) reports reduced vigor later in the season and early senescence for plants produced from seed conditioned at warm temperatures. This he partially attributed to rapid plant emergence and early tuber set. The fact that no differences in time of tuber set could be detected in this study may account for the lack of differences in foliage growth and senescence rates later in the season.

The production of large numbers of aboveground stems by the warmed seed which displayed strong apical dominance, may be explained by several factors. Moorby (1978) reported that apical dominance decreases after planting, increasing the number of stems. Allen (1978) reported that long periods of sprouting resulted in plants which had few mainstems, but many secondary stems (secondary stems may also produce tubers), and short periods of sprouting gave few main or secondary stems. Due to the fact that sprout growth was rapid at 10.0^{o}C and 15.6^{o}C, sprout breakage during cutting, handling, and planting could have resulted in a loss of apical dominance and growth of lateral buds. A combination of the above factors may explain why warming seed, which tends to increase apical dominance, results in increased stem numbers.

Results indicate that conditioning seed by storing it at 10.0^{o}C or 15.6^{o}C is a means of increasing numbers of stems per hill. Length of time in storage at these temperatures determines the number of stems produced. The ability to regulate plant types and growth patterns through manipulation of storage temperature regimes could be a means of controlling quality and quantity of yields. Since the number of tubers per stem is constant, seed conditioned at warm temperatures would result in plant types which would produce large numbers of small tubers. This would be an advantage for seed growers who desire yields of smaller sized tubers, but not for growers who desire yields for commercial sale. Holding seed continuously at 4.4^{o}C resulted in few stems, which would produce fewer tubers, but they would be of a suitable size for commercial production.

Plant growth characteristics for the different treatments were less consistent than stem counts. Data for 1984 showed that seed conditioned at the higher (10.0^{o}C) temperature did not always emerge earlier or produce more vigorous plants early in the season than seed held at 4.4^{o}C, and no differences in time of tuber set or plant senescence could be detected among treatments for either year. However, plant growth and development data for 1985 suggest that conditioning seed at high temperatures may be one method of managing plant development through manipulation of time to emergence, early plant vigor, and aboveground stem numbers per hill.

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CHAPTER III

Effects of Preplant Seed Tuber Warming on Yields of Russet Burbank Potatoes

ABSTRACT

Field experiments were conducted in 1984 and 1985 to study the effects of storage temperature and duration on yielding potential of Russet Burbank seed potatoes. Three Oregon locations were chosen, representing growing seasons of 160-190 (Hermiston), 200 (Corvallis), and 70-100 (Powell Butte) frost free days. Russet Burbank seed potatoes were stored at 4.4°C and then warmed to either 10.0°C (1984) or 15.6°C (1985) for 0, 2, 5, and 8 weeks prior to planting. Plots were arranged in a randomized complete block design. Crops were grown using cultural and pest control programs common to the areas.

Treatment effects were evident only at Corvallis in 1984, where holding seed continuously at 4.4°C significantly reduced tuber size. Yields for Hermiston and Powell Butte were unaffected by conditioning treatments. The lack of response to warm-up treatments in 1984 suggests that 10.0°C may have been too low, because the higher temperature (15.6°C) used in 1985 did significantly influence seed performance at all locations.

At Corvallis (medium-length season) in 1985, seed conditioned for 5 weeks outperformed seed held at the cool temperature in terms of fewer culls, higher U.S. No. 1 yields, and significantly higher total yields. Cool, wet, springs in the Willamette Valley delay planting and limit the length of growing season. The presence of sprouts at planting may account for yield differences, due to a combination of factors such as early plant emergence and early bulking. In 1984 holding seed continuously at 4.4°C reduced tuber size, perhaps due to late emergence, which would shorten the bulking period.

Seed held continuously at 4.4°C produced higher U.S. No. 1 yields than any other treatment at Hermiston (long season) in 1985, while seed warmed for 5 weeks significantly reduced tuber size. Delayed senescence and an extended bulking period can explain why cool stored seed produced high yields. Seed conditioned at the

high temperature produced small tubers perhaps due to early senescence and a short bulking priod.

Cool stored seed also performed well at Powell Butte (short season), producing a higher yield of U.S. No. 1 tubers than any other treatment. The reasons for higher yields from cool stored seed however, may be different for Powell Butte than for Hermiston. The Powell Butte trial experienced a severe frost in late June, in 1985, about 5 weeks after planting. Plants from cool stored seed emerged later and were generally smaller at that time than the seed warmed at 15.6^{o}C. Less advanced foliage growth at the time of frost damage, or a larger reserve of energy left in the seed piece to support rapid regrowth may account for higher yields from cool stored seed in this short season area.

The effects of storage temperature and duration on yielding potential of Russet Burbank seed potatoes appeared to be modified by length of season and climate. Both quality and quantity of yields were affected. Cool stored seed performed best in a long season production area, while seed conditioned at high storage temperatures performed best in a short season.

INTRODUCTION

It is important for both seed and commercial potato growers to be able to produce high yields of quality potatoes that command high prices. Seed storage temperature can influence both yield and quality (Toosey, 1963,1964; Iritani, 1968b; Perennec and Madec, 1980; Susnoschi, 1981ab). Conditioning of seed in storage is believed to affect crop performance through changes in physiological age of the seed. Seed stored for long periods at high temperatures is considered to be physiologically old and inferior to seed which has been stored at cool temperatures, due to the fact that it generally produces a high percentage of undersized tubers (Wurr, 1978; Allen, 1978; Iritani, 1967,1968a).

The possibility of regulating the ageing phenomenon through storage conditions to produce desired yields in a given location has been suggested (Iritani, 1983; Iritani et al., 1983; Davidson, 1958; Toosey, 1963,1964; Allen, 1978). The length of the growing season and the type of yields desired would dictate the degree of conditioning required. Seed stored at cool temperatures (physiologically young), which tends to emerge late and senesce late, may be able to utilize a long season with increased bulking time to produce high yields of U.S. No. 1 tubers (Toosey, 1964; Hartman, 1958). Short seasons, conversely, may require seed conditioned at high temperatures (physiologically old), which can emerge rapidly, establish an early canopy, set tubers early, and use as much of the limited season as possible for bulking (Toosey, 1964). Seed growers may want seed conditioned at high temperatures, because of this tendency to produce a high percentage of small tubers (Allen, 1978).

The primary objective of this study was to determine the feasibility of conditioning seed for maximum yields and quality in a given length of season.

MATERIALS AND METHODS

Climatic Characteristics of Study Sites

Refer to Chapter II p.46-47.

Treatments

Refer to Chapter II p.47.

Experimental Design

Refer to Chapter II p.48.

Planting

Refer to Chapter II p.48.

Cultural Practices

Refer to Chapter II p.48-49.

Statistical Analysis

Refer to Chapter II p.49.

Harvest and Yield Measurements

Yields and grades were determined using conventional standards for all trials. All specific gravities were determined using a hydrometer. Level-bed diggers were used at all sites, and tubers were picked up by hand.

Site 1, Hermiston. The crop was harvested on Sept. 25 in 1984 and Sept. 16 in 1985.

Site 2, Corvallis. Tubers were dug on Oct. 3 in 1984 and in 1985, the crop was lifted on Oct. 1.

Site 3, Powell Butte. The crop was lifted on Oct. 22 in 1984 and on Oct. 15 in 1985.

RESULTS AND DISCUSSION

Site 1, 1984 - Hermiston. Removing seed tubers from 4.4°C and conditioning them at 10.0°C for periods of 0, 2, 5, and 8 weeks prior to planting did not significantly influence total yield, grades, or specific gravities (Table 3.1). Although differences were not statistically significant, seed conditioned by warming at 10.0°C for 2 and 5 weeks tended to produce slightly higher total and U.S. No. 1 yields than the 0 and 8 week treatments (Fig. 3.1 A and B). Yields of undersized and cull tubers were similar for all treatments.

Lack of significant differences in response to storage treatments at the long season Hermiston site was unexpected. Iritani (1968b,1983) reported that the optimum storage temperature for keeping Russet Burbank seed physiologically young was 4.4°C; further, physiologically young seed is expected to produce high yields of large tubers in a long growing season (Allen, 1978; Toosey, 1963,1964; Davidson, 1958). It is possible that the 5.6°C temperature differential was too small to affect seed physiological age and crop performance. Also, weather and field conditions could have masked treatment affects (Perennec and Madec, 1980; Bodlaender, 1963; Fischnich and Krug, 1963).

Site 2, 1984 - Corvallis. Holding seed continuously at 4.4°C significantly reduced tuber size (Table 3.2). Seed stored at 10.0°C for 5 weeks prior to planting tended to produce higher yields of U.S. No. 1 tubers than any other treatment, although the differences were not statistically significant at the .05 level (Table 3.2 and Fig. 3.2 A). Total yields were highest for seed stored at 10.0°C for 2 and 5 weeks prior to planting, although again, differences were not statistically significant at the .05 level (Table 3.2 and Fig. 3.2 B). Several possibilities exist for explaining why seed stored continuously at 4.4°C produced more undersized tubers. Young seed tends to emerge late and set tubers late. The season might not have been long enough for maximum bulking of physiologically young seed (Wurr, 1978). Seed planted

Table 3.1. Effects of Seed Storage Temperature on Yield, Grade, and Specific Gravity of Russet Burbank Potatoes. Hermiston, 1984.

Weeks at[1/] 10.0°C	Yield, t/ha				Specific gravity
	Total	US No. 1	<4.76 cm	Culls	
0	51.0	42.2	6.8	2.0	1.083
2	53.9	44.6	7.4	1.9	1.086
5	53.9	45.3	6.8	1.7	1.085
8	51.6	42.4	7.4	1.8	1.087
LSD, .05	NS	NS	NS	NS	NS

[1/] Seed held at 4.4°C prior to conditioning at 10.0°C

Figure 3.1 A. Effects of Seed Storage on Yields of Russet Burbank Potatoes. Hermiston, 1984.

Figure 3.1 B. Effects of Seed Storage on Total Yields of Russet Burbank Potatoes. Hermiston, 1984.

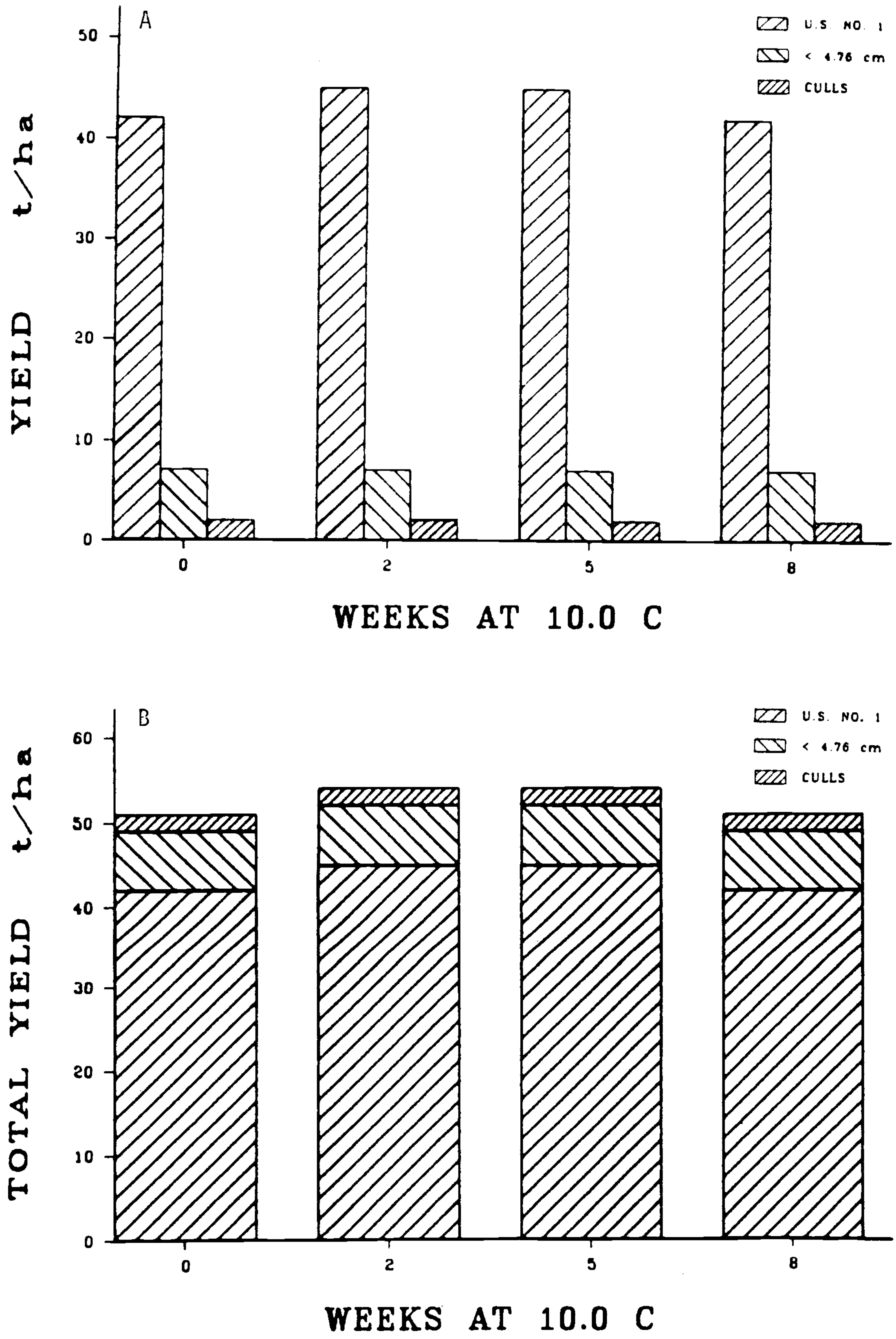

A
U.S. NO. 1
< 4.76 cm
CULLS
YIELD t/ha
0
10
20
30
40
50
0
2
5
8
WEEKS AT 10.0 C
B
U.S. NO. 1
< 4.76 cm
CULLS
TOTAL YIELD t/ha
0
10
20
30
40
50
60
0
2
5
8
WEEKS AT 10.0 C

FIG. 3.1

Table 3.2 Effects of Seed Storage Temperature on Yield, Grade, and Specific Gravity of Russet Burbank Potatoes. Corvallis, 1984.

Weeks at[1/] 10.0°C	Yield, t/ha Total	US No. 1	<4.76 cm	Culls	Specific gravity
0	51.8	18.4	21.7	11.7	1.101
2	55.2	24.1	16.1	15.0	1.097
5	55.0	26.8	15.5	12.8	1.097
8	52.8	25.0	15.0	12.8	1.074
LSD, .05	NS	NS	4.61	NS	NS
LSD, .01	NS	NS	6.62	NS	NS

[1/] Seed held at 4.4°C prior to conditioning at 10.0°C

Figure 3.2 A. Effects of Seed Storage on Yields of Russet Burbank Potatoes. Corvallis, 1984.

Figure 3.2 B. Effects of Seed Storage on Total Yields of Russet Burbank Potatoes. Corvallis, 1984.

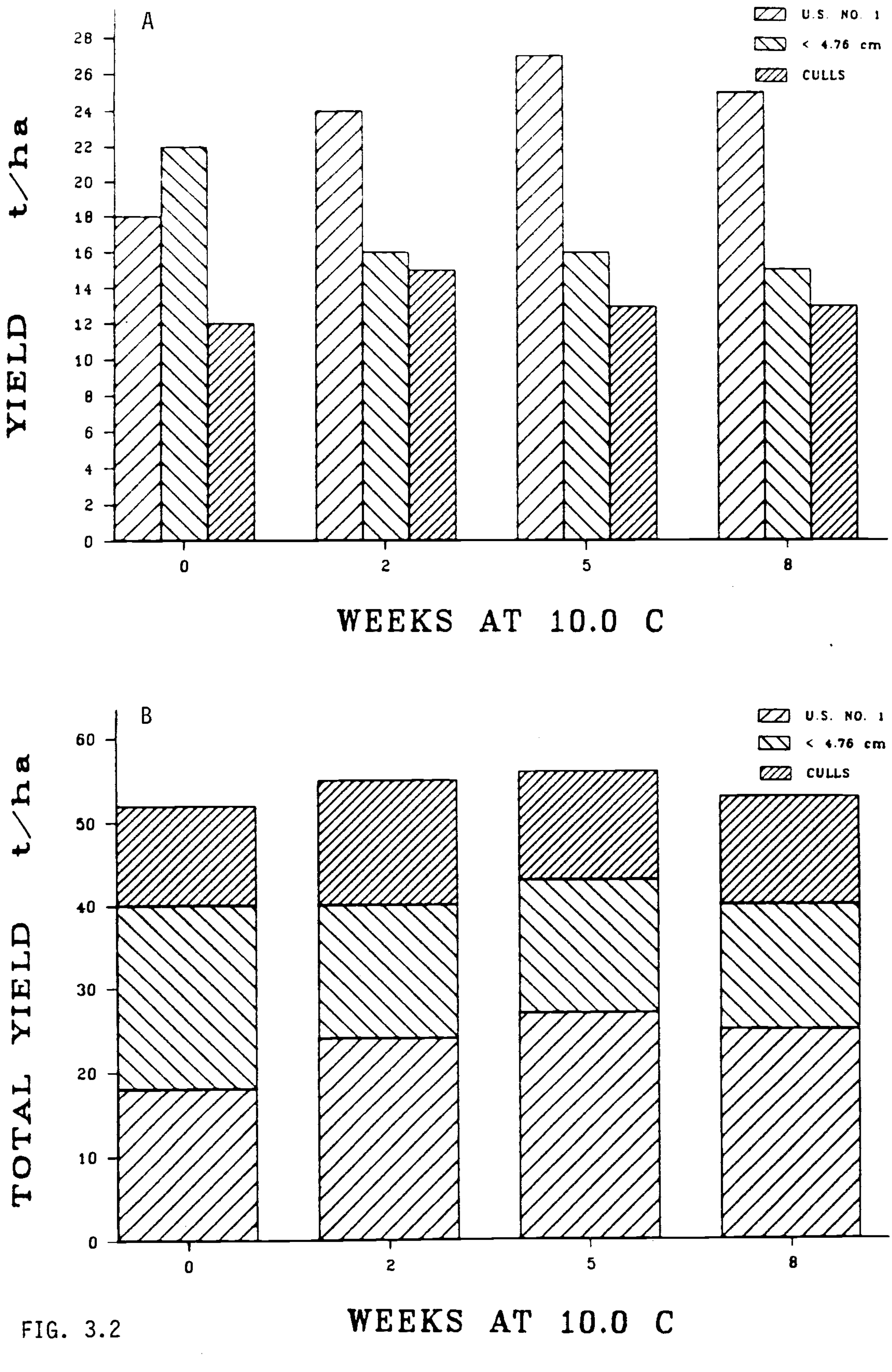

A
U.S. NO. 1
< 4.76 cm
CULLS
YIELD t/ha
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
0
2
5
8
WEEKS AT 10.0 C
B
U.S. NO. 1
< 4.76 cm
CULLS
TOTAL YIELD t/ha
0
10
20
30
40
50
60
0
2
5
8
WEEKS AT 10.0 C

FIG. 3.2

before it has reached its optimum potential in storage is said to express "juvenile degeneration" (Kawakami, 1963) and produces low, undesirable yields.

Site 3, 1984 - Powell Butte. Treatments did not significantly affect yields at the .05 level (Table 3.3). Seed warmed to 10.0^{o}C for 8 weeks prior to planting produced a slightly higher yield of U.S. No. 1 tubers than any other treatment (Fig. 3.3 A), and total yields were similar for all treatments (Fig. 3.3 B). Seed conditioned at the warmer temperature would be expected to favor high yields in a short season area (Rozier-Vinot, 1971; Iritani, 1967,1983; Headford, 1962; Toosey, 1963,1964). It is possible that field conditions play a greater role in determining yields than previously thought, or that 10.0^{o}C was not high enough to age seed significantly faster than 4.4^{o}C.

Site 1, 1985 - Hermiston. Seed stored continuously at 4.4^{o}C produced significantly higher yields of U.S. No. 1 tubers than any other treatment (Table 3.4). Seed conditioned for 5 weeks at 15.6^{o}C prior to planting produced significantly higher yields of undersized tubers than the 0 and 2 week treatments (Table 3.4). These results agree with previous reports (Iritani, 1983, Toosey, 1964,1963; Davidson, 1958) suggesting that physiologically young seed might perform well in a long season area, due to a long bulking period that offsets late plant emergence (Fig. 3.4 A). Seed conditioned for 5 weeks at 15.6^{o}C would be expected to produce a high yield of undersized tubers in a long season (Rozier-Vinot, 1971; Fischnich and Krug, 1963), due to early emergence, tuber set, and vine senescence, limiting the bulking period. Total yields were not significantly different at the .05 level, however seed stored continuously at 4.4 C produced a slightly higher total yield than any other treatment (Fig. 3.4 B).

Site 2, 1985 - Corvallis. Seed conditioned at 15.6^{o}C for 5 weeks prior to planting produced a significantly higher total yield than any other treatment at the .05 level (Table 3.5 and Fig. 3.5 B). The 5 week warm-up treatment also produced a slightly higher yield of U.S. No. 1 tubers than all other treatments (Fig. 3.5 A),

Table 3.3 Effects of Seed Storage Temperature on Yield, Grade, and Specific Gravity of Russet Burbank Potatoes. Powell Butte 1984.

Weeks at[1/] 10.0°C	Yield, t/ha Total	US No. 1	<4.76 cm	Culls	Specific gravity
0	51.0	39.1	7.0	4.9	1.086
2	51.4	38.5	6.8	6.2	1.087
5	53.1	40.4	7.3	5.4	1.086
8	52.3	41.5	5.3	5.6	1.083
LSD, .05	NS	NS	NS	NS	NS

[1/]Seed held at 4.4°C prior to conditioning at 10.0°C

Figure 3.3 A. Effects of Seed Storage on Yields of Russet Burbank Potatoes. Powell Butte, 1984.

Figure 3.3 B. Effects of Seed Storage on Total Yields of Russet Burbank Potatoes. Powell Butte, 1984.

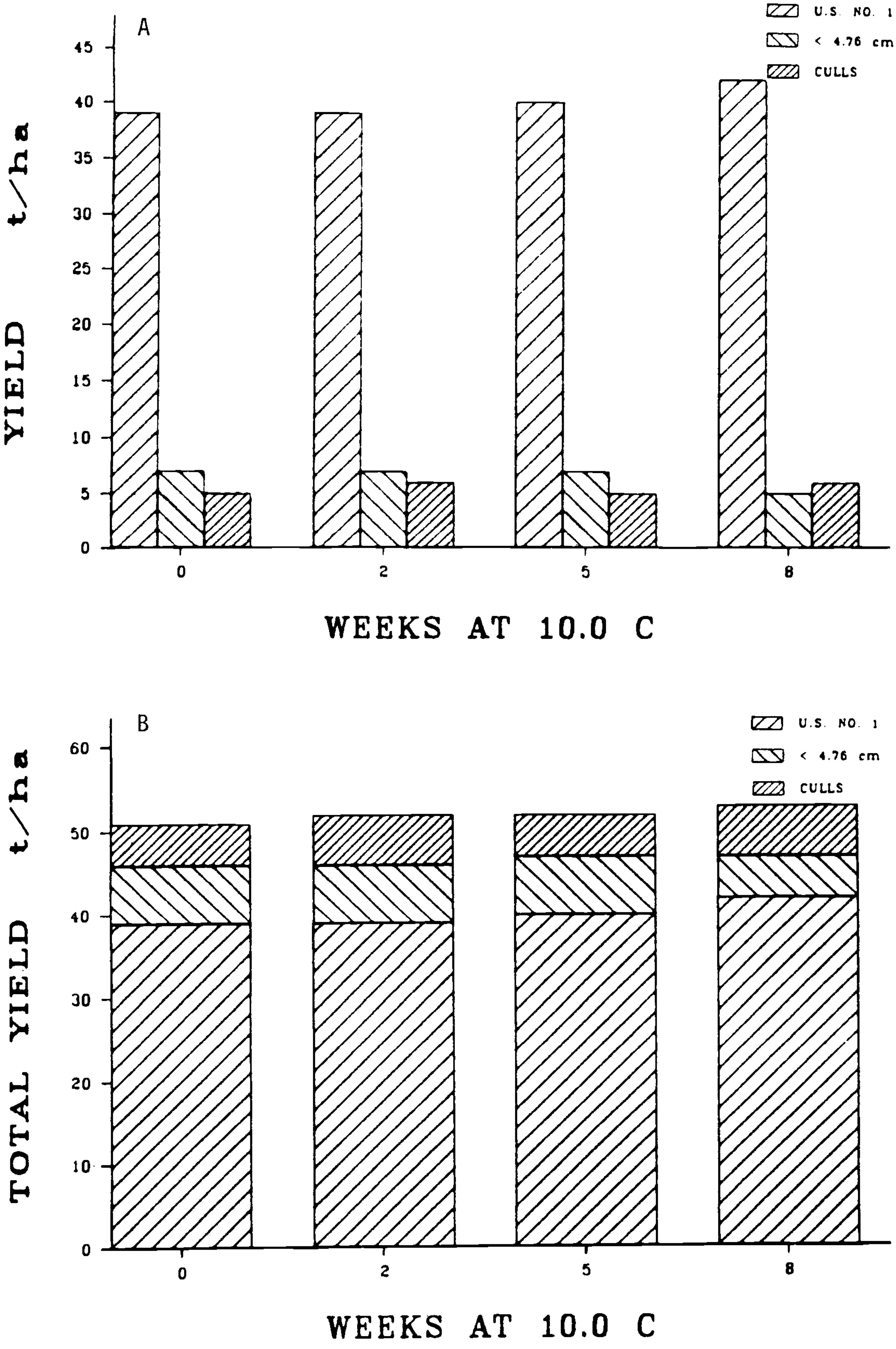

A
U.S. NO. 1
< 4.76 cm
CULLS
YIELD t/ha
45
40
35
30
25
20
15
10
5
0
0
2
5
8
WEEKS AT 10.0 C
B
U.S. NO. 1
< 4.76 cm
CULLS
TOTAL YIELD t/ha
60
50
40
30
20
10
0
0
2
5
8
WEEKS AT 10.0 C

FIG. 3.3

Table 3.4 Effects of Seed Storage Temperature on Yield, Grade, and Specific Gravity of Russet Burbank Potatoes. Hermiston, 1985.

Weeks at[1/] 15.6°C	Yield, t/ha				Specific gravity
	Total	US No. 1	<4.76 cm	Culls	
0	84.9	44.0	11.8	29.2	1.082
2	74.8	31.7	12.1	31.0	1.081
5	81.5	34.4	17.3	29.8	1.068
8	78.1	34.9	14.1	29.1	1.083
LSD, .05	NS	8.07	3.78	NS	NS
LSD, .01	NS	11.16	5.23	NS	NS

[1/] Seed held at 4.4°C prior to conditioning at 15.6°C

Figure 3.4 A. Effects of Seed Storage on Yields of Russet Burbank Potatoes. Hermiston, 1985.

Figure 3.4 B. Effects of Seed Storage on Total Yields of Russet Burbank Potatoes. Hermiston, 1985.

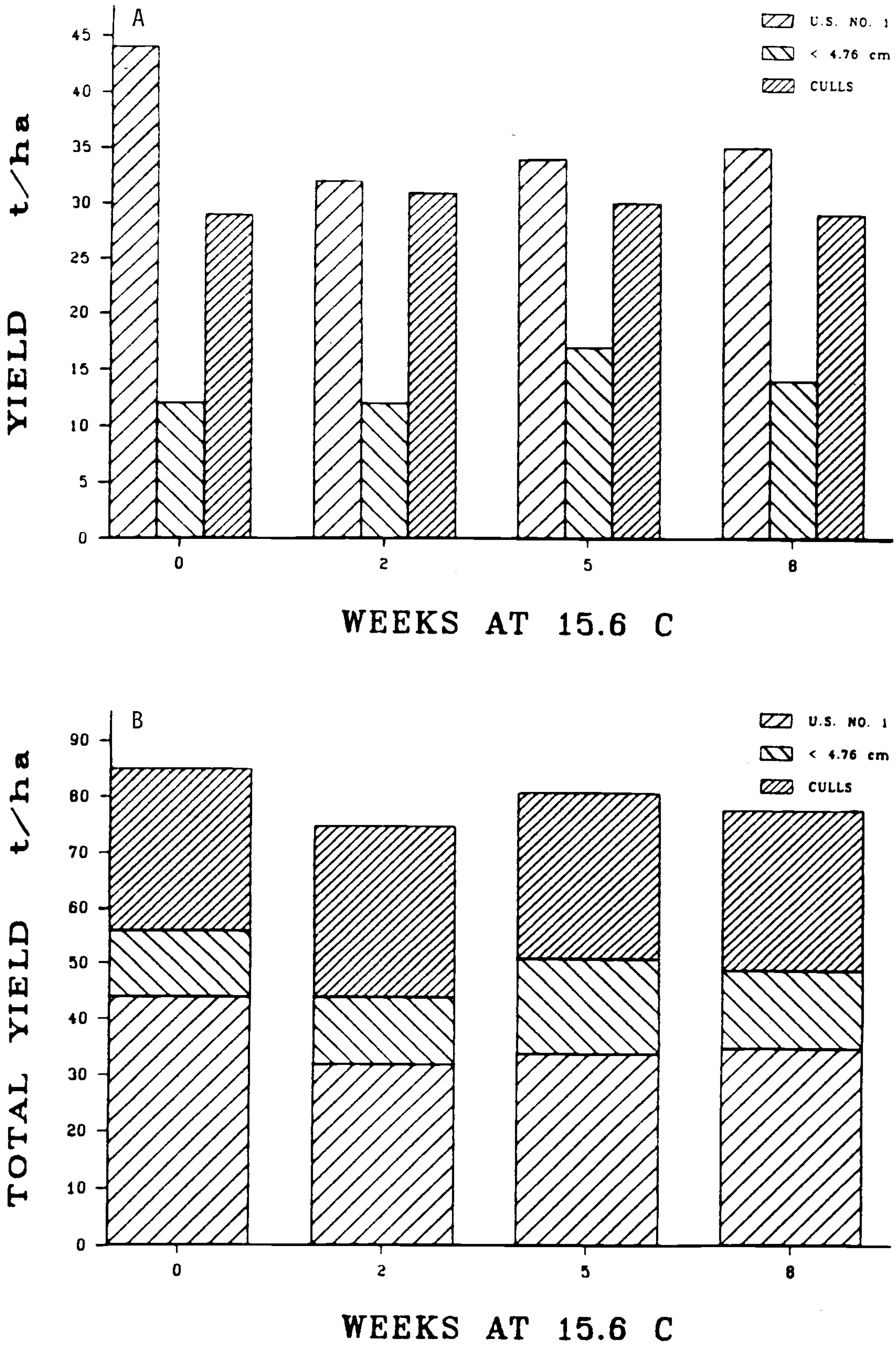

A
U.S. NO. 1
< 4.76 cm
CULLS
YIELD t/ha
45
40
35
30
25
20
15
10
5
0
0
2
5
8
WEEKS AT 15.6 C
B
U.S. NO. 1
< 4.76 cm
CULLS
TOTAL YIELD t/ha
90
80
70
60
50
40
30
20
10
0
0
2
5
8
WEEKS AT 15.6 C

FIG. 3.4

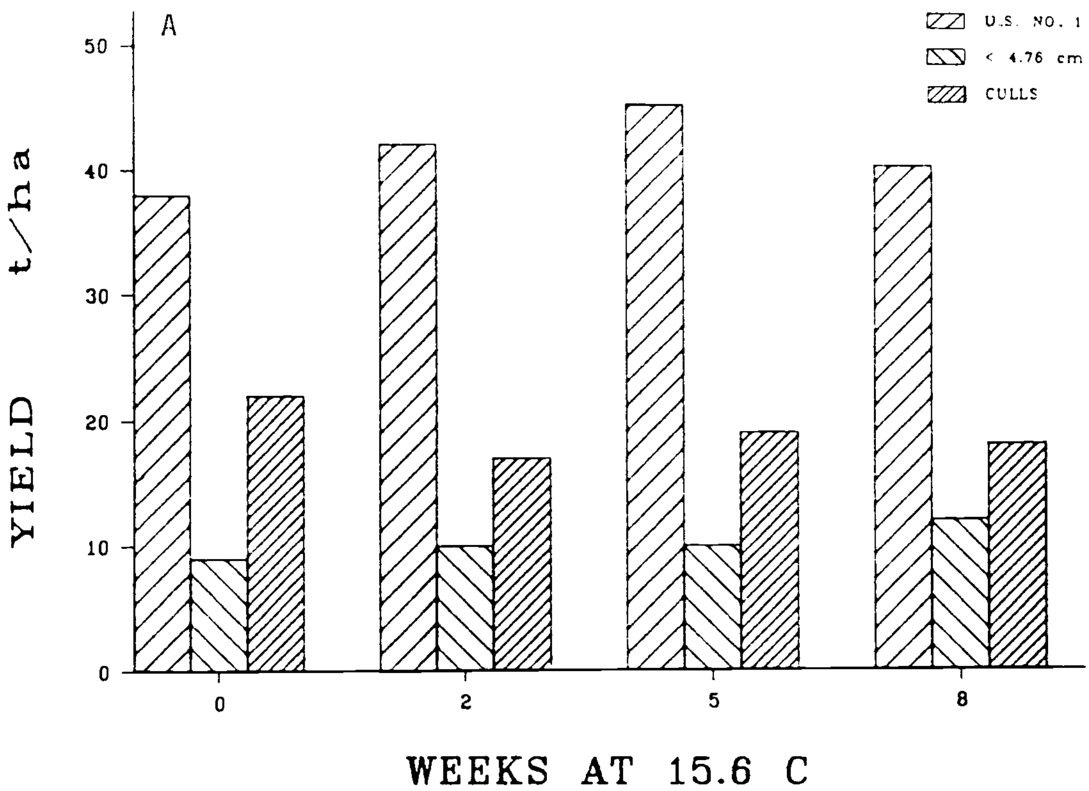
Table 3.5 Effects of Seed Storage Temperature on Yield, Grade, and Specific Gravity of Russet Burbank Potatoes. Corvallis, 1985.

Weeks at[1/] 15.6°C	Yield, t/ha				Specific gravity
	Total	US No. 1	<4.76 cm	Culls	
0	68.2	37.6	9.1	21.5	1.094
2	68.1	42.0	9.7	16.5	1.095
5	73.9	45.2	9.7	18.6	1.091
8	69.2	39.5	11.6	18.1	1.093
LSD, .05	4.41	NS	NS	NS	NS
LSD, .01	6.09	NS	NS	NS	NS

[1/]Seed held at 4.4°C prior to conditioning at 15.6°C

Figure 3.5 A. Effects of Seed Storage on Yields of Russet Burbank Potatoes. Corvallis, 1985.

Figure 3.5 B. Effects of Seed Storage on Total Yields of Russet Burbank Potatoes. Corvallis, 1985.


A
U.S. NO. 1
< 4.76 cm
CULLS
YIELD t/ha
50
40
30
20
10
0
0
2
5
8
WEEKS AT 15.6 C

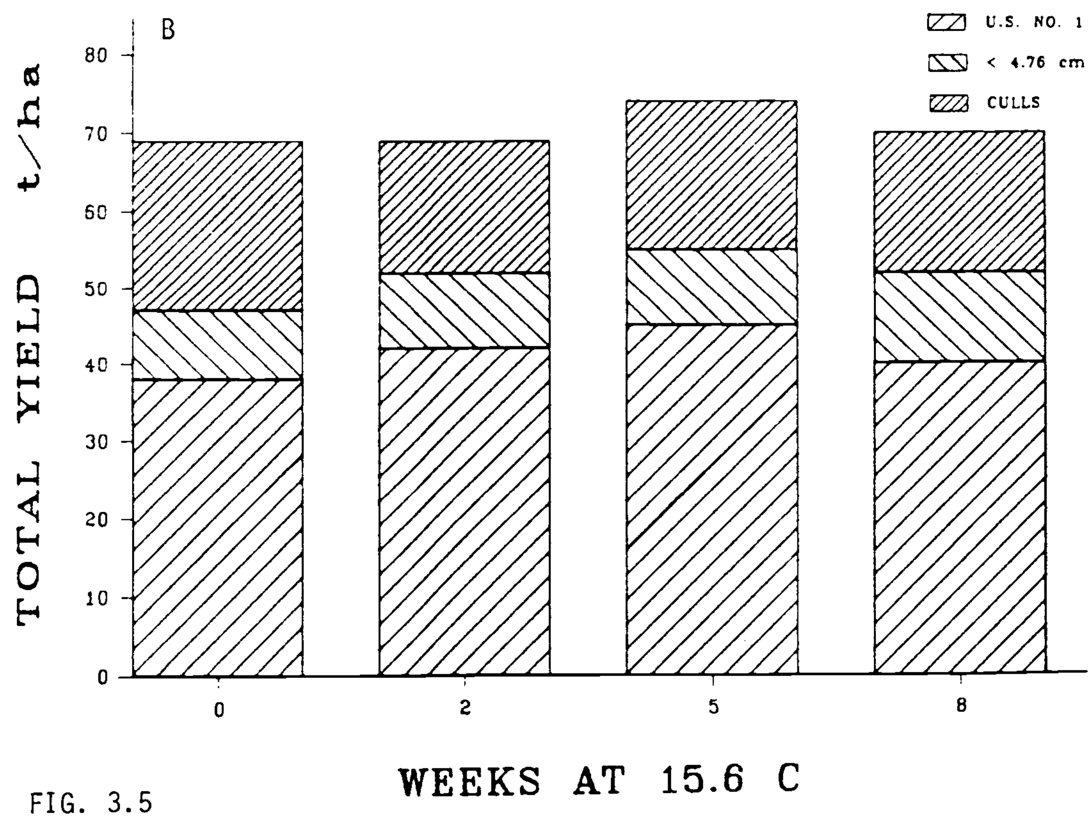

B
U.S. NO. 1
< 4.76 cm
CULLS
TOTAL YIELD t/ha
80
70
60
50
40
30
20
10
0
0
2
5
8
WEEKS AT 15.6 C

FIG. 3.5

although differences were not significant at the .05 level (Table 3.5). Corvallis has a medium length growing season with cool, wet, springs which delay tuber germination (Iritani, 1984). Physiologically young seed (cool stored) which has little sprout development at planting might be especially delayed by cold soils. Delayed emergence results in a limited time for bulking, thus reducing tuber size. It is possible that seed conditioned at a warm temperature is less adversely affected by low soil temperatures due to the presence of developed sprouts at planting. Early emergence would result in a longer time for bulking and increased tuber size.

Site 3, 1985 - Powell Butte. Seed stored continuously at 4.4^{o}C produced significantly higher yields (.01 level) of U.S. No. 1 tubers than any other treatment, and seed conditioned at 15.6^{o}C for 2 weeks prior to planting produced significantly more culls than any other treatment (Table 3.6 and Fig. 3.6 A). Total yields were similar for all treatments (Fig. 3.6 B).

According to the literature, seed stored continuously at 4.4^{o}C should not produce high U.S. No. 1 yields in a short season area with cool spring temperatures (Allen, 1978; Toosey 1964,1963). Powell Butte yields may have been affected by a late Spring frost that occurred about five weeks after planting. It is possible that plants produced from the seed conditioned at 15.6^{o}C, which tend to emerge earlier, were more severely damaged than those from seed stored at 4.4^{o}C, which tend to emerge later. Regrowth from the terminal bud may have been relatively fast for the plants produced from seed held continuously at 4.4^{o}C. due to less damage, and a larger reserve of energy left in the mother seed piece to support regrowth. Differential frost injury could explain the high yields of marketable tubers produced by the physiologically young seed stored continuously at 4.4^{o}C.

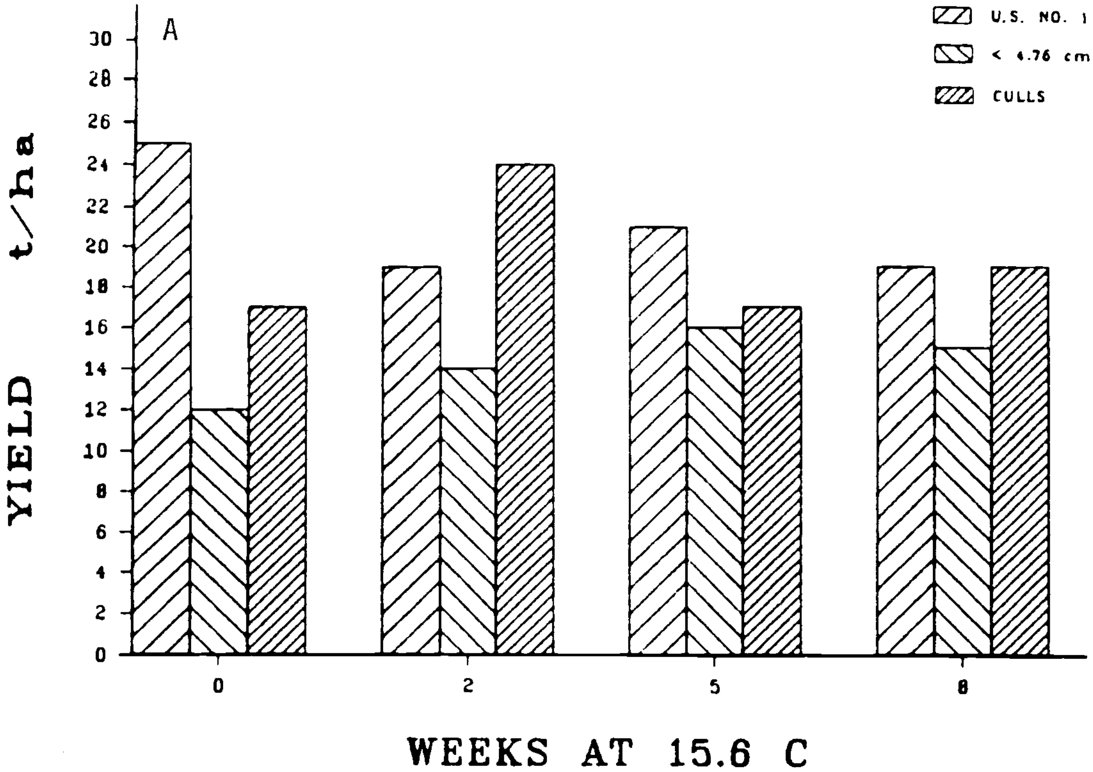
Table 3.6 Effects of Seed Storage Temperature on Yield, Grade, and Specific Gravity of Russet Burbank Potatoes. Powell Butte, 1985.

Weeks at[1/] 15.6°C	Yield, t/ha Total	US No. 1	<4.76 cm	Culls	Specific gravity
0	55.0	25.2	12.4	17.4	1.087
2	56.4	18.7	13.6	24.3	1.086
5	54.0	20.7	16.4	16.9	1.085
8	53.4	19.4	14.7	19.4	1.088
LSD, .05	NS	3.71	NS	4.56	NS
LSD, .01	NS	5.13	NS	6.31	NS

[1/]Seed held at 4.4°C prior to conditioning at 15.6°C

Figure 3.6 A. Effects of Seed Storage on Yields of Russet Burbank Potatoes. Powell Butte, 1985.

Figure 3.6 B. Effects of Seed Storage on Total Yields of Russet Burbank Potatoes. Powell Butte, 1985.


A
U.S. NO. 1
< 4.76 cm
CULLS
YIELD t/ha
30
28
26
24
22
20
18
16
14
12
10
8
6
4
2
0
0
2
5
8
WEEKS AT 15.6 C

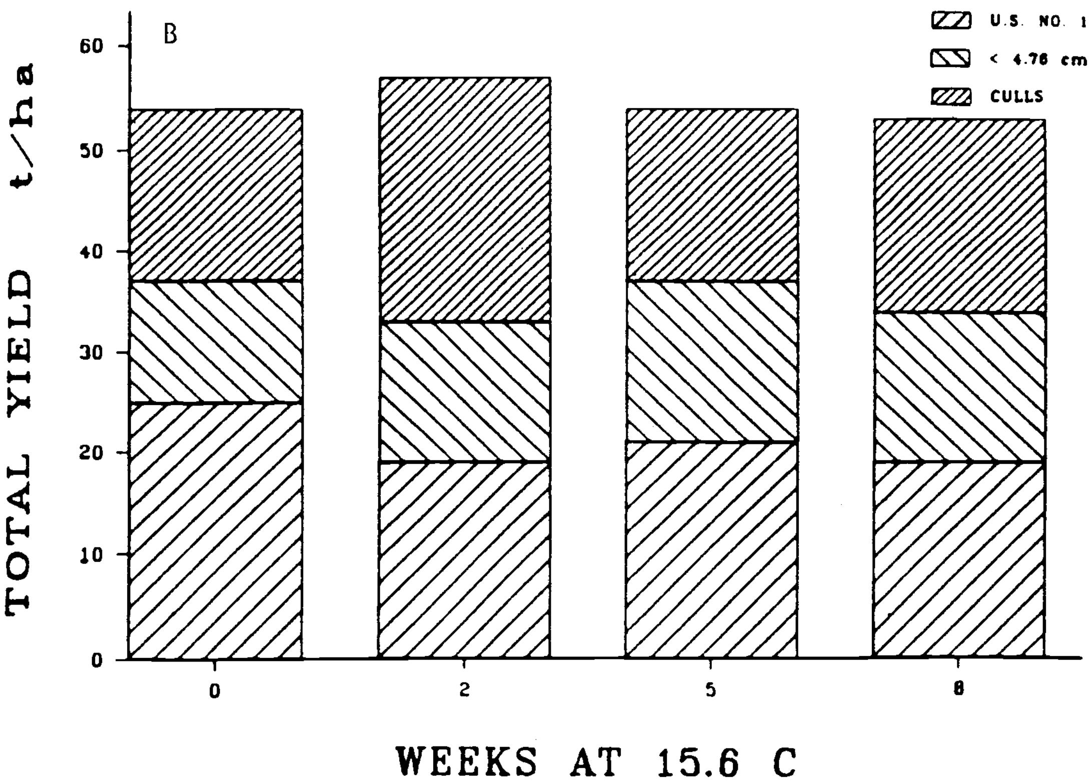

B
U.S. NO. 1
< 4.76 cm
CULLS
TOTAL YIELD t/ha
60
50
40
30
20
10
0
0
2
5
8
WEEKS AT 15.6 C

FIG. 3.6

CONCLUSIONS

The physiological ageing process is temperature dependent (Susnoschi, 1981ab; Iritani, 1968b; Davidson, 1958; Perennec and Madec, 1980). The abscence of seed conditioning effects on crop performance in 1984 may have been due, therefore, to the small 5.6^{o}C temperature differential used (4.4^{o}C vs 10.0^{o}C). This argument is supported by significant responses to the 11.2^{o}C differential (4.4^{o}C vs 15.6^{o}C) used in 1985. A less likely explanation for discrepancies is that field conditions and weather patterns could have interacted to mask treatment effects in 1984 (Bodlaender, 1963; Fischnich and Krug, 1963; Allen, 1978; Perennec and Madec, 1980).

Significant treatment differences in quality and quantity of yields were found at each location in 1985. Seed conditioned at the warmer temperature (15.6^{o}C) yielded more undersized, fewer U.S. No.1 tubers, and lower total yields than seed held constantly at 4.4^{o}C at the Hermiston trial. Considering these results, it may be impractical and even detrimental to store seed for any length of time at temperatures above 4.4^{o}C before planting in a long-season area such as Hermiston. Areas with long growing seasons have been reported to require physiologically young seed that has slow emergence, delayed senescence, and thus has a longer period of tuber bulking (Allen, 1978; Toosey, 1963,1964). Seed conditioned for 5 weeks at 15.6^{o}C produced large numbers of undersized tubers which may have been caused by low bulking rates, due to a low LAI. Physiologically older seed has a low LAI at bulking, due to early tuber set and the transport of synthates to the tuber rather than to continued foliage growth (Wurr, 1978). Physiologically older seed may also produce high yields of small tubers, due to increased stem number. Increased stem production per hill is a growth characteristic of seed conditioned at high temperatures. It has been reported that tuber size is inversely proportional to tuber number (Iritani, 1967; Iritani and Thornton, 1984). Because tuber number per stem is relatively constant, tuber size decreases with increasing stem number.

Corvallis has a temperate climate with a medium length growing season. In 1984 seed conditioned at 10.0^{o}C for 2, 5, and 8 weeks produced slightly higher total and U.S. No. 1 yields than seed stored continuously at 4.4^{o}C, although differences were not statistically significant. Seed held continuously at 4.4^{o}C did produce significantly more undersized tubers than any other treatment. In 1985 seed conditioned for 5 weeks at 15.6^{o}C produced significantly higher total yields than any other treatment and also produced a higher yield of U.S. No.1 tubers. Because of this yield advantage, warming seed for 5 weeks prior to planting may prove profitable for Willamette Valley growers. Apparently presprouted seed favors plant types which have optimum bulking rates for this medium-length season. The larger number of undersized tubers produced by seed stored continuously at 4.4^{o}C in 1984 may have reflected season length and delayed germination due to cool soil temperatures. Seed stored at low temperatures requires a long bulking period for production of large tubers, due to delayed plant emergence (Wurr, 1978). Stem numbers may have been optimum for the production of large tubers, but the short bulking period limited tuber size.

Powell Butte yields in 1985 were affected by frost in late June. Higher numbers of large U.S. No. 1 tubers produced by seed stored continuously at 4.4^{o}C in this short growing season area conflicts with previous reports (Toosey, 1963,1964) which indicate that seed stored at cool temperatures does not have enough time for sizing in a short season and thus produces high yields of small tubers. The higher yield of U.S. No. 1 tubers produced by cool stored seed may reflect an interaction of several factors. Young seed produces few stems per hill, resulting in the production of large tubers. Young seed also tends to emerge late in the season. Less severe frost damage due to less advanced foliage growth at the time of frost, coupled with low stem numbers may account for the large yield of U.S. No.1 tubers produced by this physiologically young seed.

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GENERAL DISCUSSION AND CONCLUSIONS

The transfer of seed tubers from cool to warm storage accelerates the physiological development process. Prolonged storage at high temperatures resulted in physiologically more advanced seed that favored rapid sprout development and a preponderance of sprouts near the apical (bud) end of the tuber.

Warming seed in storage hastened the end of dormancy. The metabolic status of the tuber changes as sprout initiation begins. However, in these studies, changes in levels of soluble protein, free amino acids, and reducing activity during periods of non-sprouting and sprouting did not reveal a consistent treatment effect. Metabolite contents changed similarly at both the cold and warm storage temperatures. Results suggest that using levels of these metabolites as criteria for predicting the degree of development and subsequent seed performance may not be feasible. Phosphorylase activity also changed similarly at both temperatures. Activity greatly increased five weeks after storage and remained high for two weeks, followed by a decrease to initial levels. This lends evidence to the hypothesis that perhaps this enzyme system is not responsible for starch degradation during sprouting, but may act as an activator for the primary enzymes involved. This view is supported by the fact that the time of greatest phosphorylase activity coincided with times of soluble protein decreases and free amino acid increases. Sugar levels did show consistent trends for each storage regime, although changes may have been related more to temperature effects than metabolic demands. The level of reducing and total sugars in seed tubers may indirectly reveal the extent of seed tuber ageing, provided previous storage history is known.

Although seed tuber physiological age is relative and difficult to quantify, it is apparent from this study that it should be considered a quality characteristic of the seed which could affect performance. Climate and length of season at each experiment site played a role in determining the optimum physiological age for

Russet Burbank seed potatoes. Seed tuber physiological age affected yield and quality by influencing the degree of sprout development at planting, which in turn affected numbers of stems per hill and plant growth patterns. The interaction between season length and seed tuber physiological development may be important, however. Seed designated for the three sites appeared to be similar at planting in terms of sprout development and metabolite levels, but performed differently in terms of yields at the three locations. Differences between expected and observed performance indicates the importance of length of growing season and climate on the expression of the physiological age factor.

Plants from physiologically old (warmed) seed generally emerged earlier and appeared more vigorous early in the season than plants from physiologically young (cool stored) seed. Expected differences in time of tuber initiation and vine senescence among treatments may have been too subtle to visually detect in these tests. Numbers of aboveground stems per hill increased at all three sites with increasing time at the elevated storage temperatures. Several factors such as sprout breakage, which could have increased lateral branching, lessened apical dominance after planting, (increasing axillary buds), and increased secondary stem production, may have been responsible for the production of more stems from sprouted seed. It is well documented that increases in numbers of stems per hill increase the number, but decrease the size of tubers. However, in this study, more stems per hill did not result in a high percentage of undersized tubers at all locations, just as plant types with few stems per hill did not produce high yields of large tubers at all locations. Apparently differences in yield appear to be related to growth patterns and seasonal effects as well as plant types.

Physiologically young (cool stored) seed performed well at Hermiston, producing large yields of U.S. No. 1 tubers, while the seed warmed for 5 weeks produced a high proportion of undersized tubers. The long growing season of this area allows for a long bulking period and is well suited to physiologically young seed which produces plant types that emerge and senesce late, and produce few stems per hill. Plants from the physiologically older (warmed) seed emerge and senesce early, and therefore have a short bulking period. This short bulking period, coupled with increased numbers of stems per hill, probably accounted for the tendency toward small tubers from the physiologically old (warmed) seed.

As expected, seed treatments performed differently at Corvallis than they did at Hermiston, due to the shorter season. Seed held at the cool temperature produced more undersized tubers, while the seed warmed for 5 weeks produced a higher total yield and a slightly higher yield of U.S. No. 1 tubers. These results are consistent with observations about the Hermiston planting and generally agree with the literature. Physiologically young (cool stored) seed emerges late, and may have unusually slow rates of sprout growth at Corvallis, due to cool wet conditions. As noted above, late emergence shortens the bulking period, and therefore reduces yield potential and tuber size in a short season area such as the Willamette Valley. The physiologically older (warmed) seed produced plants which emerged early and probably set tubers early, allowing for a long bulking period which resulted in high total yields, even though numbers of stems per hill were relatively high.

Powell Butte yields did not fit the expected pattern. Due to an even shorter growing season than Corvallis, it was expected that late emergence of plants from physiologically young (cool stored) seed would produce a high percentage of undersized tubers, and that plants from older (warmed) seed would produce a higher U.S. No. 1 yield. The cool stored seed however, produced a larger yield of U.S. No. 1 tubers than any other treatment. This may have been due in part to the fact that the already short Central Oregon growing season was shortened even more by a frost approximately one month after planting, in 1985. Delayed emergence of plants from younger (cool stored) seed may have resulted in reduced foliage damage; further, it is possible that greater tuber energy reserves may have afforded a more rapid regrowth of plants from the young seed. It is clearly difficult to accurately predict yields from a particular seed treatment if the crop experiences atypical weather conditions for the area. Further tests dealing with seed tuber physiological age and frost injury are needed.

The results from each study site suggest that early or late plant emergence and the length of the growing season determine the length of the tuber bulking period, and thus affect yield and quality. Apparently the effects of plant growth patterns and season can override the effects of plant types, as indicated by the fact that increased numbers of stems per hill resulted in high yields at one location and reduced tuber size in another.

Manipulating the physiological age of seed tubers by conditioning them at high storage temperatures prior to planting affects growth patterns and plant types. The expression of the physiological age factor in terms of yields is then influenced by seasonal and climatic characteristics of the growing site. Conditioning seed at elevated temperatures (increasing the physiological age) appeared to reduce yields of large tubers in a long season area, but tended to increase yields in a short season area. Seed stored at cool temperatures (physiologically young) performs oppositely, producing high yields of U.S. No. 1 tubers in a long season and a high percentage of undersized tubers in a short season. It appears that it may be feasible to condition seed at a specific temperature prior to planting for maximum yields and quality in a given production area.

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