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Pre-harvest foliar desiccation of Yellow Globe Danvers onions was investigated as a means to improve harvest procedure and to reduce storage losses. Foliar desiccation tended to increase storage disease and sprouting incidence versus the untreated controls. Paraquat approximately doubled storage disease in both years. Stoddard solvent and ethephon increased disease in lesser amounts. Endothall at 1.1 kg a.i./ha gave disease results equal to the control. Root sprouting increased with most treatments but not to such a degree as to compromise commercial value. Neck moisture was efficiently lowered by most desiccant treatments but the final neck moistures achieved by the treatments did not correlate with subsequent disease or sprouting. Phenolic concentration in neck tissue was studied for several treatments and a weak negative correlation was found with subsequent disease in storage. Bulb size did not appear to be affected by the desiccant treatments. A study of mineral redistribution in untreated bulbs during the top senescence process in the month preceding harvest showed that nitrogen declined in neck tissue by 50% and in leaf tissue by 25%. Phosporus and zinc also declined in both tissues by 50% or more. Potassium declined in leaf tissue by ca. 50% but showed a 25% accumulation in neck tissue. Calcium and boron more than doubled in neck tissue and increased at a slightly

lower rate in leaf tissue. Copper increased ca. 50% in both organs. Iron and aluminum showed a strongly correlated accumulation pattern in both tissues, accumulating at rates in excess of 500%. Magnesium and manganese showed no consistent change in concentration.

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LITERATURE REVIEW

Successful onion production in western Oregon demands the minimization of storage quality losses (40,76). These losses can be the result of several factors, singly or in combination. An important factor is the destruction of part of the stored crop by one or more plant pathogens. Also of importance is the development of non-pathogenic disorders and the early breaking of dormancy. It has been widely reported that the harvest curing process is central to the control of stored product losses in northern-grown onions (40,76,80,81). This review will examine several aspects of the curing process which influence the quality of the stored onion bulb.

Onion Growth and Development

The onion is a biennial plant. The growth in the first year is normally vegetative with a day-length induced bulb formation (29). Top growth occurs most rapidly at or above $20^{\circ}C$ while roots show a somewhat lower optimum closer to $15^{\circ}C$ (15,78,88). The growth of the whole plant is positively correlated with increasing light intensity and temperature up to a certain maximum (15). Total leaf area as a percentage of total plant weight will increase with decreasing light intensities (15). The new leaves emerge through a lateral slit at the top of the leaf base of each preceding leaf (28). In this manner, a long, leafless 'stem' is produced. The sheathing base of each leaf completely encircles the stem. With the onset of bulbing, leaf emergence declines and then stops (29). Root emergence and growth also slows down. The unemerged leaves and the already present leaf bases begin to swell with water and carbohydrates to produce the bulb (28). This produces an increasingly hollow 'false stem' supporting a rather large mass of foliage. The neck functions as a temporary storage organ for reducing sugars translocated from the leaves (85). Eventually, the neck region begins to soften. Softening of the neck is characterized by a movement of the sugars into the bulb and a reduction of total neck fresh weight. Soon the foliage collapses at the neck. Whether the softening and collapse are a result of mechanical shear stress due to the weight of the tops against decreasing neck size or a more directed process is as yet unknown (40). Top-fall is the standard indicator of approaching onion maturity (1,31,40,66) but is not thought to be totally reliable for scheduling harvest decisions (65). There are no phenological reports in the literature which relate changes in soluble solids, total dry matter, firmness, or other factors to harvest suitability. Even after collapse, there is good evidence that the vascular connections between the foliage and bulb are not severed and that translocation and transpiration continue for some time (5,53). Timing of foliar collapse has been linked to

(1) Planting density: The bulb in higher densities (and thus smaller bulbs) will fall earlier (19).

(2) Length of longest leaf: A longer leaf length will result in earlier top-fall. There is a positive association between short leaf length and a longer leaf production period. A longer leaf production would delay the hollowing of the 'false stem' (20). Lower light intensities have been shown to induce longer, narrower leaves (15).

(3) Soil nitrogen: High nitrogen levels are correlated with

delayed top-fall. There is a positive correlation between high N levels and a prolonged period of leaf production (40,76). Nitrogen deficient onions also do not mature normally. The bulbs are small and the tops refuse to fall (66,85). This is in contrast to the situation of a high planting density which produces small bulbs which mature earlier. There is some indication that roots do not die back in N deficient onions as is the case with normally maturing bulbs (66). Other researchers have found no consistent N effect (26).

(4) Soil phosphorus: High levels of phosphorous have been shown to cause earlier maturity (10).

(5) Soil moisture: Later than normal irrigation (or rain) generally slows top-fall. There is a positive correlation between soil moisture status and leaf production period (40). Root regeneration may play an important role in the timing of foliar collapse (5). Sparse evidence suggests that soil moisture status interacts with temperature and internal growth factors to regulate the process (5,15,51).

(6) Temperature: High temperatures will promote earlier bulbing and earlier maturity (15,40,57).

(7) Hormone balance: Application of ethephon (which breaks down to release ethylene) to photoinduced seedlings has been found to hasten bulbing and maturity while significantly reducing ultimate yield (18,48,51).

(8) Seedstalk formation: Onions can be induced to bolt to seed in the first season of growth if the low temperature inductive

stimulus is received at the critical early stage of growth (40). Formation of the seedstalk effectively prevents normal lodging.

Harvest Curing Practice

In commercial curing practice, onions are lifted from the soil and placed in windrows to air and sun dry. This procedure is initiated when one-half or more of the tops have fallen naturally (40).

Curing changes the onion in several respects. First, it gradually reduces the moisture in the neck and foliage. This causes a tightening of dead scales around the bulb and neck. It is expected that onion bulbs will lose about 3-5% of their weight during this period (54). Good storage capability has been positively associated with firmness and high dry-matter content and negatively with moisture content, especially neck moisture, at time of storage (22,39,56). Scale number will increase with earlier maturity (10,53) but other factors such as mineral nutrition, soil moisture, and cultural practices do not show a predictable influence on scale number (6). Scale thickness has been found to be little influenced by the size of the bulb (46). Second, curing causes the development of cultivar characteristic scale coloration and other associated phenolic compounds (30,35,79). Quercetin and derivatives, catechol, protocatechuic acid, and chlorogenic acid are the predominant flavanol and phenolic compounds (30,47,49,50,67,73). Phosphorus and copper both tend to improve bulb coloration (57).

Third, bulbs cured with tops intact generally lose water from the neck and foliage more rapidly than those that are topped at lifting (53). Hoyle has analyzed the interaction between stage of maturity when the bulbs are topped and the length (neck) of topping (31). He found that moisture loss (physiological shrinkage) was highest if bulbs were harvested with tops up and green and lowest with tops down and dry. Rots were lowest with tops down and dry. Topping flush with the bulb resulted in less shrinkage and less rot loss than all the other treatments. Some Polish scientists found a 30-40% yield increase if harvest was delayed from the time that 25% of the tops were bent over until all the leaves were bent over and dry (45). However, delaying harvest until leaves were complete dry or removing leaves when they were still all green impaired storage quality.

During curing, certain compounds (as yet not fully characterized) which influence the root and shoot dormancy of the onion are translocated from the foliage to the meristems in the bulb.

Post-harvest Diseases

The neck rot fungus (*Botrytis allii*, Munn) is an important pathogen of western Oregon onions (76). Symptoms of neck rot infection are not readily seen in the field but can become rapidly apparent in storage (59). The pathogen has long been thought to overwinter in field debris in the soil (80) but recent work in England by Maude and Presely indicates that seed-borne inoculum is an important inoculum source (59). They found that seed treatment with the systemic fungicide, benomyl, in the spring will substantially reduce neck rot incidence at storage in the fall. However, if the disease becomes established in the crop during the growing season, it may spread rapidly by wind and rain to uninfected foliage, especially in periods of cool and moist weather (16). In the field, sporulation is generally confined to necrotic or near necrotic foliar host tissue (16). The upper foliage is usually the initial site of infection. The pathogen then grows slowly down the foliage and, if unchecked, into the neck and bulb. This development is virtually symptomless in the field (59). Rapid desiccation of the neck and foliage at curing is thought to present an unfavorable low moisture environment in the neck which hinders further mycelial penetration into the bulb (24,76,80). Large and succulent necks at harvest are known to be especially susceptible to infection (80). Rain during the curing period is known to dramatically increase neck rot incidence (40,79). The presence of a seedstalk greatly encourages bulb infection (40). The pathogen is not thought to spread to other bulbs in storage (16) but pre-infected bulbs commonly show progressive deterioration in storage. A substantial amount of work by J. C. Walker and his associates has implicated several phenolic compounds (catechol and protocatechuic acid) present in dry outer scales as capable of conferring resistance to the neck rot organism (49,50,79). Water soluble extracts from the dry outer scales of resistant colored cultivars were shown to cause poor germination and poor germ tube growth of the pathogen (79). A good correlation was found between the intensity of scale coloration and the relative amounts of inhibitory compounds both between and within cultivars (79). It was emphasized that once the hyphae penetrate to succulent tissue, this line of resistance breaks down (4). Scale cracking during curing and/or storage can render a bulb temporarily susceptible to infection (40). Artificial heat curing of onions has been found to increase scale coloration and by implication, scale phenols (35). This has been correlated with a reduction of neck rot incidence. Kulfinski and Pappelis (47) demonstrated that exposure of succulent bulb scales to the atmosphere for 48 hours before inoculation with <u>B. allii</u> increased cell nuclear area, increased nuclear dry mass, RNA, and protein, but not nuclear DNA. This was correlated with increasing quantities of chlorogenic acid in the outer scale and increased resistance to infection from _B. allii_. Later work indicated that exposure of the bulb to the ambient atmosphere at 25°C for 48 hours resulted in the accumulation of 18 mg of chlorogenic acid/gram of fresh outer scale tissue. This quantity of chlorogenic acid was found to be fungistatic to _B. allii_. The 8 mg of caffeic acid naturally found per gm of fresh tissue stimulated the germination of _B. allii_ spores (61). Other research has determined that with germinating spores of _B. allii_ on succulent leaf tissue, there is a sharp increase in epidermal flavanoids and chlorogenic acid (69). Gusar and Saveleva (25) attributed resistance of onions to _B. allii_ infection to the differing capacity of various cultivars to produce antibiotic substances in response to infection rather than to pre-existing compounds. They state that the pathogenesis of _B. allii_ is based on its capability to degrade the constitutional and induced antibiotic substances of the onion. Onion phenolics have also been implicated in resistance to _Colletotrichum circinans_ (Berk.) Vogl. and _Botrytis cinerea_ Pers. (17,80). Phenols have not been shown to have any influence on infections by _Aspergillus niger_ van Tiegh. and _Peronospora destructor_ (Berk.) Casp. (67,80).

The evidence for phenolic involvement in field host resistance is at best somewhat circumstantial. Wood (86) points out that considerable caution must be exercised in interpreting such evidence, especially that the compounds and quantities obtained must be in an anatomical, physiological, and biochemical position to exert an impact upon the pathogen in the natural infection process.

Walker and Maude (77) have analyzed the occurence of Gliocladium roseum on mycelia and sclerotia of B. allii and found that in culture, G. roseum produced substances inhibitory to the growth of B. allii. In addition, the presence of G. roseum in close contact with B. allii on inoculated onion tissue reduced the rate of infection. Whether this has any field relevance is not clear.

Fusarium basal rot (Fusarium spp.) is a relatively minor fungal pathogen of stored bulbs from the Lake Labish area of western Oregon. It is soil-borne and is thought to invade through basal wounds or through old root scars (80). It is favored by high temperatures and wounds caused by machinery and insects.

Bacterial storage rots are an increasing problem on Lake Labish. Irwin has recently completed a study of these pathogens (32). He distinguished two storage disease symptom types. Type I is characterized by decay starting at the neck and progressing down through one or two fleshy scales near the outer surface of the bulb. Occasionally, one inner set of scales may be affected. This disease is known by the growers as 'slippery skin' and is the most common of the two bacterial rots. Irwin's research indicates that Pseudomonas cepacia is responsible for this symptom development. Type II storage symptoms are characterized by scale infection throughout the interior of the bulb with only a few outer scales remaining intact. This infection is known by the growers as 'stinking rot'. The pathogen responsible for these symptoms was identified as Erwinia-like.

Both diseases are incited by prolonged periods of high relative humidity and the presence of free water on plant surfaces. Type I field symptoms (correlated to type I storage symptoms) can be seen from early

June onwards whereas type II field symptoms are only common after late June. Type I shows a chlorosis and desiccation of the outer onion leaves with a gradual infection of the emergingyounger leaves. The infection may be symptomless for some time and may be retarded or occasionally eliminated by extremely unfavorable (to the pathogen) environmental conditions such as low relative humidity and high temperatures. Type II infection is much more dramatic and can lead to complete destruction of the emerged leaves in 24-48 hours. Type I symptoms are most common following late season rains, either before or after lifting. Spread in the field for both diseases appears to be the result of wind and water splash. Prolonged irrigation can increase infection and the use of surface water to irrigate can also increase infection. Kawamoto and Lorbeer (44) indicate that _P. cepacia_ is primarily a wound pathogen which spreads rapidly in watersoaked (congested) or physically injured tissues. The presence of the hollow seedstalk provides easier entrance for the bacterial pathogens. Mechanical injury may double the rate of infection. Both soft rot bacteria are thought to overwinter in the soil on crop debris. There is no indication that either pathogen will spread to other bulbs in storage unless conditions within the store are extremely damp.

Post-harvest Disorders

In western Oregon, the non-pathogenic disorders arising out of the curing process are sun-scald and translucent scale. Both are related to bulb temperatures just prior to and during curing. Sunscald is a direct function of exposure of the bulbs, usually while in windrows, to high temperatures (81). The bulb is essentially 'cooked' at the point of greatest exposure, resulting in cell disorganization and subsequent scale shrinkage as water is lost from the affected area. Diameter of the injury is usually ½-2 inches and can extend from one to four scales deep. It is common for the site of sunscald injury to become secondarily infected by bacterial pathogens.

Translucent scale is a physiological disorder characterized by one to several scales becoming transparent and watersoaked. Outer scales are more affected than inner ones (81). Microscopic examination reveals a disintegration of the parenchyma and a disorganization of cell contents. Work by Lipton et al. (52) demonstrated that high temperatures during late season growth increased the incidence of the disorder. Delays between the completion of curing and cool storage also served to increase the disorder. It is often associated with sunscald but that is not an absolute requirement. Larger bulbs (>7.5 cm) were more susceptible. The exact physiological cause of the disorder is still unknown.

Post-harvest Breaking of Dormancy

The resumption of root or shoot growth while in storage is a final category of post-harvest loss. It is necessary to maintain stored onion bulbs in a dormant condition to meet the demands of the market. Lake Labish growers may store their crop for up to eight months after harvest.

At full maturity (tops down and yellowed) the onion shoot meristem is at rest (1,40). There is evidence that root growth does not experience rest but rather an environmentally imposed dormancy (1). Rooting has been found to be independent of temperature but positively correlated with relative humidity (87). Root excision of bulbs will greatly retard shoot sprouting (1). Both Thomas (71), Stow (68) and Kato (42) have determined that there are inhibitors which are produced in the leaves and translocated into the bulb during leaf senescence which promote rest. Thomas (71) could not detect absisic acid (ABA) but Tsukamoto (74) identified its presence in an ethyl acetate fraction. Stow (68), however, was unable to correlate the level of ethyl acetate soluble inhibitory substances present in bulbs after harvest with bulb dormancy. Thomas and Isenberg (72) postulated a change in inhibitor-promoter balance which breaks rest. Analysis of stored bulbs led them to conclude that an auxin-inhibitor balance controlled sprout activation and gibberellic acid controlled shoot extension. Cytokinins were thought to play a role in meristem cell division soon after rest was broken. Subsequent research (2) implicated cytokinins as the primary promoters. Mahotiere, et al. (58) showed that kinetin and sucrose were capable of promoting growth in excised shoot meristems of resting onions whereas IAA and two GA species were not. ABA inhibited the growth of shoots. A GA biosynthesis inhibitor was found to be able to inhibit growth if applied before a 10° C treatment but not if applied after such a treatment. Aung, et al. (7) found more total GA in dormant versus non-dormant bulbs and suggested that GA activity was more related to mobilization and use rather than internal concentration.

Warm and moist storage conditions will promote the resumption of both root and shoot growth (40). Modern commercial practice utilizes a foliar spray of 30% maleic hydrazide (MH-30) to enhance natural bulb rest. The spray is usually applied when 50% of the tops have fallen in the field. The compound is translocated to the plate meristem of the bulb so it is critical that the leaves still be green when the spray is applied (35). Harvest application of MH-30 will prevent the rise in respiration associated with sprouting in untreated bulbs (83). Isenberg, et al. (37) determined that MH-30 induced a disturbance of normal hormone balances in stored bulbs. Cytokinin levels were significantly reduced, gibberellin cycles were altered, auxin activity was low, and the inhibitor fraction was maintained at a higher level. Cells of the meristem showed abnormal enlargement without normal production of mitotic figures. Cell death in the meristem was also promoted. The effect of MH-30 is overcome by the bulb to lead to a much delayed sprouting. The exact mechanism of maleic hydrazide action is still unknown.

Top Desiccants

Northern-grown onions are cured and harvested in the fall. Most areas usually experience dry weather during the harvest period. However, rain is an everpresent threat to the field curing process. Several studies have been conducted on the use of foliar desiccants to improve harvest procedures. Kaufman and Lorbeer (43) investigated the use of desiccating salts (sulfates of magnesium, copper, and ammonia and chlorides of calcium and magnesium) on topped bulbs which have been inoculated with *B. allii* on the fresh neck surface. All of the salts showed significant levels of control with calcium chloride being the most effective. Isenberg and associates have performed a series of studies with neo-decanoic acid (NDA) as an onion foliar desiccant. Their objectives were to reduce foliage moisture rapidly such that mechanical harvesters would not become clogged with succulent leaves and secondarily to reduce the incidence of neck rot. Their first study (62) utilized cultivars of variable inherent storage quality. They found all NDA treatments produced higher rot incidences. The increase was non-significant in the long-storing cultivar 'Copperskin' but in the two early season varieties 'Grandee' and 'Orange County Yellow Globe' the incidence of increased rots for NDA treatments was highly significant. It was noted that 'double' bulbs were particularly affected. NDA was found to significantly accelerate water loss from the foliage and necks. A second experiment (36) with two long-storing cultivars 'Downing Yellow Globe' and 'Northern Oak' confirmed that NDA could desiccate onion foliage sufficiently (65% moisture) to permit earlier machine harvest. Neither cultivar showed significant increases in rot incidence. Similar results as to neck moisture were recorded for NDA experiments conducted in England (34). No data on rot incidence was given for those experiments.

Zschau and Böttcher (89) investigated Diquat and Paraquat as foliage desiccants. They found an improved level of machine efficiency but also a greatly increased rate of rots and sprouts in storage. A second series of experiments by Böttcher, et al. (11) utilized the desiccants dimexan and CKB 1028A. They found that there were variable increases in rots over the control treatments, with severe problems in an especially rainy harvest season. They also noted an increase in storage shoot sprouts with both compounds. The compounds were felt to have value in allowing better scheduling and operation of harvest machinery. Further experiments (12) found that aminophon was preferable to dimexan as a desiccant. With aminophon, bulbs were lifted eight days earlier and curing time was reduced 3-6 days over control treatments. Yields were reduced 4-5% but size was unchanged (presumably due to a lower dry matter content). In ambient stores, aminophon treated bulbs sprouted 4.3% more, lost 0.5% more weight, and rotted 1.1% less than untreated onions. The overall loss was 3.6% over untreated bulbs similarily stored. When the bulbs were held in cold storages, there were no differences between treated and untreated bulbs.

Rickard and Wickens (65) found that the use of dimexan appreciably reduced harvested bulk, a significant cultural advantage. However, this was accompanied by increased losses due to neck rot. The treatment did not significantly reduce harvested weight. Stow (68) investigated the use of dimexan and found no relationship between time of desiccation or desiccation itself and the amount of rots that developed. However, a significant amount of root and shoot sprouting was observed. Aoba (5) also noted that foliar desiccation increased sprouting. Burr (14) investigated both paraquat and endothall (Des-i-cate) as foliar desiccants and found high incidences of neck rot at the higher rates of both sprays (paraquat at 3 pints/A and endothall at 3 gal/A). Both paraquate rates greatly increased the incidence of translucent scale. He also found that bulbs stored with wet, green necks showed relatively little neck rot. Theyalso showed little shrinkage and translucent scale. The reason for the good performance of the uncured controls remains obscure.

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FOLIAR CHEMICAL DESICCATION AND ONION STORAGE QUALITY[1/]

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Abstract. The use of several compounds to desiccate onion tops prior to harvest was investigated. Most chemicals, rates, and timings caused an increase in post-harvest disease and sprouting versus untreated controls. Endothall at 1.1 kilogram active ingredient/hectare had storage losses comparable to the control. Paraquat substantially elevated storage decay at all rates. Ethephon and stoddard solvent increased storage losses to a lesser extent. Subsequent disease in storage was not found to be correlated with the neck moistures produced by the spray treatments. Phenolic concentration in neck tissue was studied for several treatments and a weak negative correlation was found with subsequent disease in storage. Other possible explanations for the desiccant-induced disease and sprouting increases are briefly discussed.

Post-harvest losses are common in stored onions (17). Pre-harvest foliar desiccation has been studied as a means to reduce disease incidence in storage. The experimental rational has been two-fold. First, by reducing the time required to field cure onions, disease aggravating rains might be avoided. Second, by rapidly reducing foliage and neck moistures, the migration of pathogens down into the bulb might be stopped. In practice,

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desiccation treatments have often increased storage losses due to disease. Isenberg and Abdel-Rahman (6), Pendergrass, et al. (11), and Richardson et al. (12) found that desiccation produced drier necks and foliage in a shorter period of time than conventional field curing practices. However, all researchers found generally higher storage losses in the desiccant treatments. No experiment showed a good correlation between low neck moisture of the desiccant treatments and reduced disease in storage. Böttcher, et al. (3), Burr (4), Rickard and Wickens (13), and Zschau and Böttcher (18) all found a similar increase in disease loss with the use of desiccants; whereas Stow's (14) results were inconclusive for disease incidence. Böttcher, et al. (3) noted a great increase in disease over untreated controls if desiccant treatments experienced rain prior to storage. Root and shoot sprouting were increased in storage in several desiccant experiments (2, 14).

However, top desiccation offers some important cultural benefits. Harvest maturity date may be manipulated with desiccants which allow more efficient harvest scheduling (3). Desiccation also reduces the volume and moisture content of field debris producing better operation of harvest machinery (6, 13) and a reduction in the amount of field debris moved into storage with onions (13). Thus, the field advantages have encouraged additional research into compounds which might function effectively as desiccants without significantly decreasing storage quality.

MATERIALS AND METHODS

Experiments were conducted in 1975 and 1976 in commercial Danvers Yellow Globe onion fields on Lake Labish muck soil, Marion county, Oregon. A split-plot design was used with four replications in 1975 and three in

1976. Blocks were 3.8 m long by 1.0 m (4 rows) wide. Chemical treatments were applied with a compressed air plot sprayer. Chemicals tested were as follows: Endothall (7-oxabicyclo (2.2.1) heptane-2, 3-dicarboxylic acid as the mono (N,N-dimethylakamine) salt from Agchem-Decco Division Pennwalt Corp., Monrovia, CA) at .56, 1.11, and 4.4 kg active ingredient /ha; Paraquat (1,1'-dimethyl-4,4'-dipyridilium dimethylsulfate from Ortho-Chevron) at .14, .56, and 1.1 kg a.i./ha; Ethephon (2-chloroethylphosphonic acid syn. 'Ethrel' from Amchem Products, Ambler, PA) at 1.1, 2.2, and 4.4 kg a.i./ha and Stoddard Solvent petroleum fraction at 238, 475, and 950 l/ha. X-77 surfactant (alkaryl polyethylene glycol with free fatty acids and isopropanol, Kalo Laboratories, Kansas City, MO) was added at 0.55% to each treatment except Stoddard Solvent. In 1975, the first application was made 5 days after normal commercial application of maleic hydrazide (MH-30) sprout inhibitor. Lifting occurred 12 days after the first spray and 5 days after the second. The bulbs field cured in the windrows for 9 more days. Considerable rain (1.80 cm) fell prior to and again just after the first spray application. In 1976, the first application was was made 4 days after MH-30 application and 4 days before lifting. Second application was 2 days later. Bulbs cured in the windrows for 16 more days. Three days after lifting, approximately 1.27 cm of rain fell on the windrowed onions. In 1975, onions were stored at 5°C and 80-85% relative humidity with little airflow. The 1976 treatments were held in a commercial onion storage facility. Temperatures fluctuated between 4.5-10°C with ca. 80% relative humidity and good air movement. Neck moisture content was determined by overnight vacuum drying at 60°C a 2.5 cm section of tissue excised directly above the bulb shoulder. Eight neck samples per treatment were used in 1975 and 12 in 1976. Incidence of disease and root sprouting were determined on 50 bulbs per replication after 5 months in storage, using symptom expression for diagnosis determination. Diagnosis of the causal agents of storage disease was made with the cooperation of the Department of Botany and Plant Pathology of Oregon State University. No attempt was made to rate severity of disease expression. Tissue for phenolic determination was freeze-dried and stored under vacuum until analyzed. Total phenolic concentration was determined according to Anderson and Todd (1) using chlorogenic acid as the standard.

RESULTS AND DISCUSSION

With few exceptions, desiccant treatments produced lower neck moistures than the control treatments in 1975 and 1976 (Tables 1 and 2). Ethephon was the most consistently effective compound. Endothall and Paraquat also showed good desiccating ability. Stoddard Solvent treatments were inconsistent. Heavy rainfall at the start of the 1975 trials may account for the generally higher pre-storage moisture values in that year. Preliminary results obtained in 1974 (12) indicated a reduction in bulb size with some desiccant treatments, especially Paraquat. The 1974 treatments had been applied quite early in the curing season in comparison to subsequent experiments. Analysis of the 1976 trials showed no statistically significant differences in final size catagories among the treatments. This does not rule out the possibility of signficant size reduction if desiccants are applied to onions at an earlier physiologic age.

In 1975, disease in storage was split almost equally between neck rot (*Botrytis allii*, Munn.) and *Pseudomonas* bacterial rots as described by Irwin (5). In 1976, the bacterial rots accounted for 73% of the diseased bulbs. Neck rot was present in 29% of the cases. There was little tendency for the two diseases to be found together. Basal plate rot (*Fusarium* spp.) was rarely found. While bacterial disease was clearly dominant among the treatments in 1976, there was no indication that any one treatment favored one pathogen over another since control plots showed about the same distribution.

Virtually all desiccant compounds tested caused an increase in storage disease in comparison to the unsprayed controls (Tables 3 and 4). Storage disease incidence was generally higher in the more humid 1975 season. The Paraquat treated onions showed a significantly higher incidence of disease as compared to the control treatments in both years. In 1975 and 1976, Endothall applied at 1.1 kg a.i./ha produced disease losses comparable to the control plots. Applications at both the 4.4 and .56 kg rates gave inconsistent and generally poorer results. Ethephon and Stoddard Solvent gave usually greater, though not statistically significant incidences of storage disease than the control. Higher application rates of Stoddard Solvent produced more disease than lower rates of the same material. In 1975, there was a significantly lower ($p<.05$) disease incidence in the later spray series. In 1976, even though the sprays were applied within two days of each other, the early treatment showed significantly less disease in storage. There was no correlation in either 1975 or 1976 between the neck moisture of the treatments at storage and the ultimate incidence of storage disease ($r\leq.50$).

Bulb size was positively correlated to storage disease (Table 5). Further analysis showed that this was due to the more pronounced development of bacterial disease in the larger bulb classes. Neck rot, however, was found in approximately the same size class distribution as non-diseased bulbs.

In 1975, root sprouting in storage was higher in the desiccant plots than the control (Table 3). The early Endothall treatments showed significantly increased sprouting. The earlier desiccant applications showed a trend toward greater sprouting but the difference was not statistically significant. Root sprouting was more pronounced overall in 1976 (Table 4). This may have resulted from higher storage temperatures in that year (4.5-10°C versus 5°C in 1975). In 1976, no treatment rooted at a significantly higher or lower rate than the control. There was no significant difference in sprouting of shoots between early and late treatments.

No correlation was found between bulb neck moisture at storage and subsequent premature root elongation in storage in either years' trials. In addition, there was no correlation between storage disease and root regrowth in either season. Root sprouting was negatively correlated to bulb size, i.e. the smaller the bulb, the more likely it was to sprout in storage (Table 5).

Phenolic concentration in neck tissue was evaluated during the pre-storage period for five of the treatments (Tables 6 & 7 and Figure 1). Control treatment necks were found to have a significantly higher phenolic concentration when averaged over all sample dates. All treatments showed increasing neck phenolic levels as top senescence progressed. However, the high variability of the samples did not allow any conclusions to be drawn between treatments on a given sample date. Early desiccant treatments produced lower neck phenolic concentrations than later treatments. Treatment disease incidence in storage generally corresponded to average phenolic concentration in the treatments tested. However, correlation was not significant. Comparison between treatment disease incidence and phenolic concentration at given sample dates shows a significant correlation ($P<0.05$)

only for the final sample date. No correlation was found between bacterial disease and phenolic concentration or neck rot and phenolic concentration by treatment when the two were analyzed independently. No correlation was found between sprouting in storage and phenols in neck tissue for any treatments.

Our results confirm those of earlier studies that foliar desiccation tends to increase onion disease in storage. Our experiments also show that some chemicals, rates, and timings are less destructive than others. The nature of these differences is not resolved. Clearly, some treatments alter plant resistance to disease penetration and migration. Desiccants may be acting on the leaf and neck tissue in several ways. Some possibilities include the physical disruption of the cuticle, changes in stomatal function and resistance, alteration in the synthesis, stability, and transport of phytoalexins (especially the phenolic group), and chemical toxicity to the plant cells. Phenolic concentration in bulb necks as influenced by various chemical desiccants may play a role in storage disease. Our evidence lends some support to this idea. The precedent for possible phenolic involvement in neck rot resistance has been documented (9, 15, 16). However, *B. allii* is known to sporulate on dead or dying tissue. The rapid creation of this condition by paraquat application might also explain the high disease incidence with this treatment. It will have to be shown that particular phenolic compounds are present in such quantity and physiological position as to exert an impact upon pathogens in the natural infection process before the relationship can be deemed valid. There have been no reports linking phenolic compounds with bacterial resistance in onions. The work of Kawamoto and Lorbeer (8) indicates that the onion bacterial pathogen *Pseudomonas cepacia* is primarily a wound pathogen which spreads rapidly in watersoaked and injured tissues. In general, chemical desiccation, especially when followed by rain, produces this wounded and watersoaked neck and foliage environment. It may be important, therefore, that the differences in anatomical resistance of onion leaf tissue to bacteria when desiccated by various chemicals be further studied.

Premature sprouting of roots in storage tends to be increased by top desiccation although the results were not consistent. Any increase would likely be due to the interruption of the biosynthesis and/or transport of native dormancy-promoting compounds found in the foliage or interruption of the transport of the applied sprout inhibitor MH-30 into the meristem of the bulb. In general, the degree of root sprouting that was evident would not compromise the value of the crop and thus would not be an obstacle to commercial desiccant use.

The cultural benefits from chemical foliage desiccation of onions will continue to provoke new research into materials and methods which do not aggravate storage disease and sprouting. Recent advances in neck rot control through seed treatment (10) improve desiccant prospects. More precise knowledge of the etiology of disease development on desiccated onion foliage will improve the probability of finding materials and methods which are both culturally effective and at the same time do not reduce the storage potential of the onion.

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Table 1. Desiccant effects on neck moisture in Danvers onions in 1975.

Treatments	kg a.i./ha[y]	4 Sept	8 Sept	13 Sept	18 Sept
		Percent moisture			
Early Series[x]					
Ethephon	4.4	88.44 b[z]	79.60 b	74.16 de	56.10 f
"	2.2	87.02 b	86.40 a	71.53 e	66.67 e
Paraquat	1.1	92.18 a	86.45 a	80.68 abc	76.80 cd
"	.56	89.28 ab	85.33 a	76.65 de	68.77 de
Endothall	4.4	88.48 b	86.00 a	80.97 abc	75.75 cde
"	1.1	89.36 ab	85.08 a	71.62 e	67.59 de
Stoddard Solv.	950 l/ha	87.10 b	84.81 ab	86.20 a	79.67 bc
"	475 l/ha	87.02 b	84.45 ab	79.58 abcd	67.98 de
Late Series					
Paraquat	1.1		85.50 a	84.03 ab	73.57 cde
"	.56		84.07 ab	78.73 bcd	76.55 cde
Endothall	4.4		86.33 a	83.46 ab	72.97 cde
"	1.1		83.38 ab	81.63 abc	74.02 cde
Stoddard Solv.	950 l/ha		85.33 a	86.03 a	89.28 a
"	475 l/ha		82.62 ab	86.07 a	87.42 ab
Control		86.50 b	84.70 ab	86.03 a	86.07 ab
$s_{\bar{x}}$		1.03	1.67	2.04	3.02
n		8	8	8	8

x Early series applied 12 days before lifting and late series 5 days before lifting.
y Active ingredient in kilograms per hectare.
z Mean separation within columns by Duncan's multiple range test, 5%.

Table 2. Desiccant effects on neck moisture in Danvers onions in 1976.

Treatments	a.i./ha[y]	9 Sept	11 Sept	15 Sept	20 Sept	23 Sept	27 Sept
		Percent moisture					
Early Series[x]							
Ethephon	2.2	86.16 c[z]	89.25 a	83.08 ab	74.25 ab	70.83 cde	61.00 e
"	1.1	87.66 abc	89.00 a	79.61 abc	74.00 ab	69.67 de	64.42 de
Paraquat	.14	88.83 ab	89.08 a	84.33 ab	79.50 ab	69.50 de	74.25 abc
Endothall	1.1	89.58 ab	86.67 a	82.33 ab	76.67 ab	77.00 abcd	68.75 bcde
"	.56	89.83 a	88.75 a	81.08 abc	73.83 b	64.33 e	69.92 bcd
Stoddard Solv.	475 l/ha	88.91 ab	87.41 a	84.17 ab	77.17 ab	73.75 abcd	67.08 cde
"	238 l/ha	87.08 bc	98.50 a	78.08 bc	75.50 ab	69.50 de	70.67 abcd
Control		89.16 ab	87.08 a	84.50 a	76.08 ab	75.16 abcd	76.91 ab
Late Series							
Ethephon	2.2		89.83 a	81.58 ab	75.92 ab	74.50 abcd	63.50 de
"	1.1		89.00 a	75.41 c	72.00 b	76.75 abcd	67.75 cde
Paraquat			87.16 a	84.08 ab	75.33 ab	77.75 abc	70.83 abcd
Endothall	1.1		87.67 a	85.75 a	74.08 ab	72.83 bcd	71.16 abcd
"	.56		89.58 a	84.83 a	77.25 ab	79.25 ab	69.75 bcd
Stoddard Solv.	475 l/ha		90.08 a	82.67 ab	81.42 a	80.91 a	74.67 abc
"	238 l/ha		88.50 a	85.33 a	81.50 a	80.58 ab	69.75 bcd
Control			89.33 a	85.58 a	79.41 ab	76.33 abcd	78.50 a
$s\bar{x}$		.79	1.02	1.91	2.22	2.38	2.55
n		12	12	12	12	12	12

x Early series applied 4 days before lifting and late series 2 days before lifting.
y Active ingredient per hectare in kilograms.
z Mean separation within columns by Duncan's multiple range test, 5%.

Table 3. Desiccant effects on incidence of storage disease due to neck and bacterial rots and root sprouting in 1975.

Treatments	kg a.i./ha	Disease %[z]	Root Sprout %[z]
<u>Early Series</u>[x]			
Ethephon	4.4	12.3 abc	1.3 ab
"	2.2	14.8 abc	.7 ab
Paraquat	1.1	24.5 a	5.8 a
"	.56	24.4 a	1.1 ab
Endothall	4.4	21.1 ab	4.7 a
"	1.1	7.6 c	6.6 a
Stoddard Solvent	950 1	16.3 abc	.5 ab
"	475 1	9.8 bc	6.2 a
<u>Late Series</u>			
Paraquat	1.1	20.2 ab	1.7 ab
"	.56	12.4 abc	1.3 ab
Endothall	4.4	14.7 abc	2.5 ab
"	1.1	6.3 c	3.3 ab
Stoddard Solvent	950 1	16.3 abc	1.5 ab
"	475 1	11.0 bc	.5 ab
Control		8.3 c	0 b
$s\bar{x}$		2.80	3.36
n		4	4

x Early series applied 12 days before lifting and late series applied 5 days before lifting.

z The arc-sine transformation was utilized for statistical analysis. Mean separation within columns by Duncan's multiple range test, 5%.

Table 4. Desiccant effects on incidence of storage disease due to neck and bacterial rots and root sprouting in 1976.

Treatments	kg a.i./ha	Disease %^{z}	Root Sprout %^{z}
Early Series			
Ethephon	2.2	3.8 ab	7.7 a
"	1.1	0.9 abc	1.7 ab
Paraquat	0.14	5.1 a	4.4 ab
Endothall	1.1	1.3 abc	3.2 ab
"	0.56	0.2 bc	3.6 ab
Stoddard	475 1	5.7 a	6.0 ab
Solvent	238 1	1.3 abc	1.3 ab
Control		0 c	5.0 ab
Late Series			
Ethephon	2.2	2.1 abc	0.2 b
"	1.1	5.7 a	6.0 ab
Paraquat	0.14	4.8 a	0.2 b
Endothall	1.1	3.1 ab	3.4 ab
"	0.56	5.0 a	2.2 ab
Stoddard	475 1	6.7 ab	5.6 ab
Solvent	238 1	2.7 bc	4.1 ab
$s\bar{x}$		2.81	3.47^z
n		3	3

x Early series applied 4 days before lifting and late series 2 days before lifting.

z The arc-sine transformation was utilized for statistical analysis. Mean separation within columns by Duncan's multiple range test, 5%.

Table 5. Relationship of bulb diameter to root sprouting and disease incidence of untreated control onions.

	Percentage in each bulb diameter (mm) class					
	0-50	51-63	64-76	77-89	90+	X*[z]
General population	10	35	39	14	2	
Root-sprout population	28	49	20	3	0	-4.34**[y]
Total disease population	3	28	40	24	5	2.31*
Bacterial disease population	4	23	39	27	7	2.94**
Neck-rot disease population	0	43	38	19	0	.81 ns

z Chi-square analysis of the ordered 2 x c contingency table by the method of A. Goldstein (1964) Biostatistics, MacMillan Co., New York.

y * Significant at $p < .05$ in comparison with the general population.
** Significant at $p < .01$ in comparison with the general population.

Table 6. Average total phenolic concentration in onion neck tissue as influenced by desiccant treatments in 1976[x].

Treatment	kg a.i./ha[y]	Total phenolic concentration[z] (mg/g dry weight)
Early Series Paraquat	0.14	58.1 c
Late Series Paraquat	0.14	61.3 bc
Early Series Endothall	1.1	64.7 abc
Late Series Endothall	1.1	68.3 ab
Control		72.2 a
$s\bar{x}$		2.8
n		20

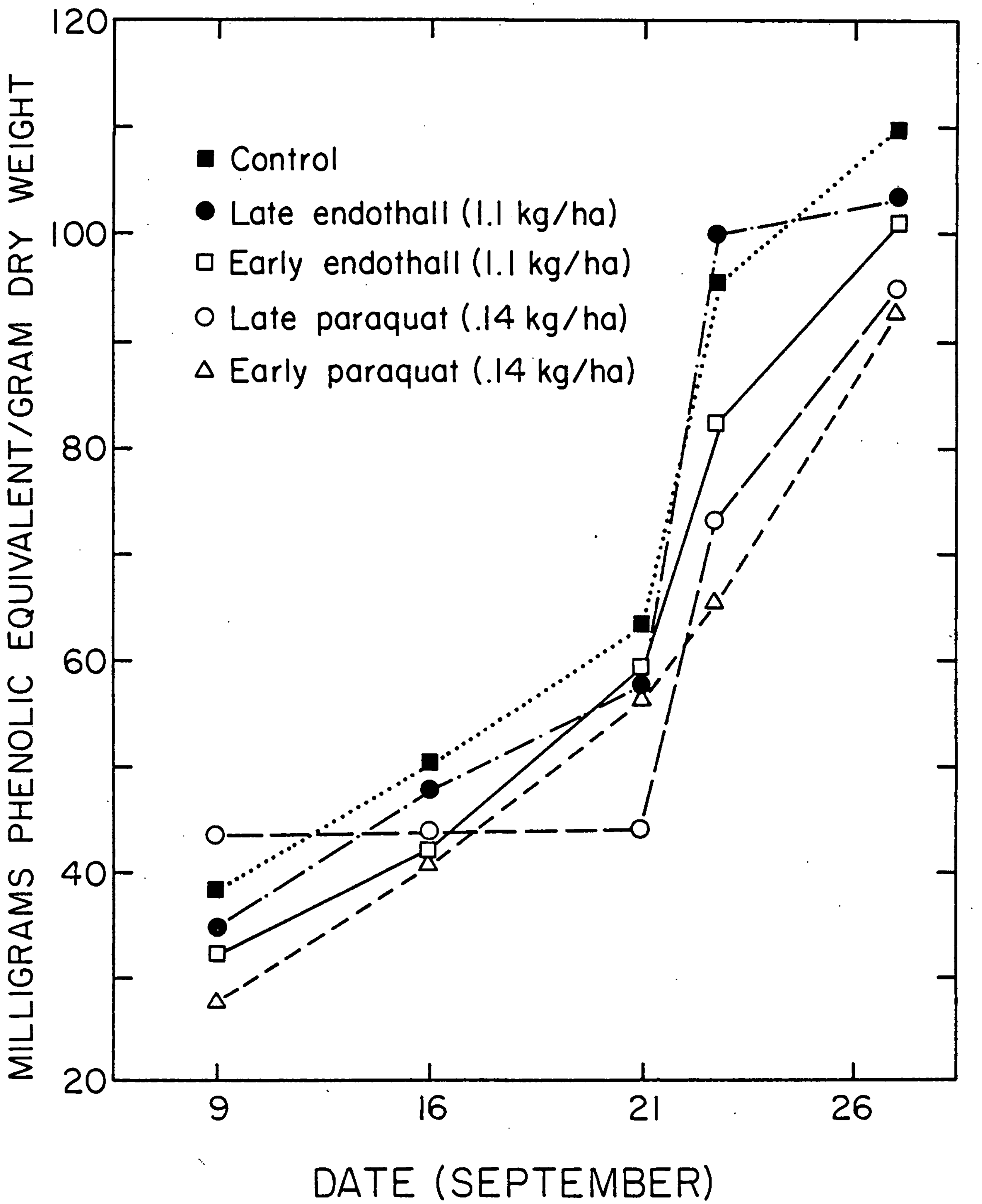
x Averaged over 5 sample dates and 4 replications.
y Active ingredient (in kilograms) per hectare.
z Mean separation by Duncan's multiple range test, 5%.

Table 7. Phenolic concentration in neck tissue by treatment over time - 1976.

Treatment	Milligrams phenolic equivalent/gm dry weight by date				
	11 Sept	15 Sept	20 Sept	23 Sept	27 Sept
<u>Early Series</u>[x]					
Paraquat (0.14 kg/ha)	30.4 c[y]	43.1 a	57.5 a	65.6 b	94.1 a
Endothall (1.1 kg/ha)	35.4 bc	44.0 a	59.3 a	84.0 ab	101.0 a
<u>Late Series</u>					
Paraquat (0.14 kg/ha)	44.6 a	45.1 a	47.1 a	75.4 ab	94.5 a
Endothall (1.1 kg/ha)	37.3 b	43.9 a	58.0 a	100.2 a	102.1 a
Control	39.7 ab	52.0 a	64.2 a	95.0 ab	110.4 a
$s_{\bar{x}}$	1.66	5.83	6.13	8.90	5.09
n	4	4	4	4	4

x Early series applied 12 days before lifting and late series 5 days before lifting.
y Mean separation within columns by Duncan's multiple range test, 5%.

Figure 1: Phenolic concentration in onion neck tissue from several desiccant treatments as a function of time.


120
100
80
60
40
20
MILLIGRAMS PHENOLIC EQUIVALENT/GRAM DRY WEIGHT
Control
Late endothall (1.1 kg/ha)
Early endothall (1.1 kg/ha)
Late paraquat (.14 kg/ha)
Early paraquat (.14 kg/ha)
9
16
21
26
DATE (SEPTEMBER)

ONION LEAF AND NECK MINERAL COMPOSITION DURING MATURATION [1/]

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Abstract. The pattern of major and minor element distribution in onion leaves and necks was analyzed at intervals during the bulb maturation and neck senescence process. Nitrogen declined in neck tissue by 50% and in leaf tissue by 25% measured on a dry weight basis. Phosphorus and zinc also declined in both tissues by 50% or more. Potassium declined in leaf tissue by ca. 50% but showed a 25% accumulation in neck tissue. Calcium and boron more than doubled in neck tissue and increased at a slightly lower rate in leaf tissue. Copper increase Ca. 50% in both tissues. Iron and aluminum showed a strongly correlated accumulation pattern in both tissues, accumulating to concentrations of five fold over initial values. Magnesium and manganese showed no consistent change in concentration. The changes in mineral nutrition are correlated with several indices of physical growth and maturation. Implications of the changes in the pattern of mineral nutrition are briefly discussed.

There is relatively little known about the physiological changes which occur during onion senescence. Brewster (5) has noted that alteration in the timing of maturity and senescence could play an important

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role in increasing onion yields. In addition, the role of the senescence process in promoting onion dormancy may become more important if the commercial sprout inhibitor, maleic hydrazide, becomes unavailable. Existing studies of onion leaf mineral nutrition (2, 4, 9, 13, 15, 16) have generally been done over a broad time span and tend to ignore the senescence process as such. In this study, changes in the pattern of major and minor element distribution in onion leaves and necks were analyzed at 4 day intervals during the maturation period.

MATERIALS AND METHODS

The experiment was conducted in 1976 in a commercial Danvers Yellow Globe onion field on Lake Labish muck soil, Marion county, Oregon. Physical measurements and neck and leaf samples were collected at 9:00 a.m. on each sampling date. All physical indices for each date were derived from 25 randomly selected plants. Top-fall was rated by squeezing the necks of the bulbs in the field to determine whether they were firm = 1, medium = 2, or soft = 3. Onions were sprayed with the sprout inhibitor MH-30 on September 3 and lifted on September 11. For mineral analysis, one bulk leaf sample consisted of the youngest mature leaf from 6 plants. Each sampling date had four replications. One bulk neck sample had six necks and two reps were run for each sample date. Samples were thoroughly washed in distilled water and vacuum dried at 60° C. Total nitrogen was determined by a modified Kjeldahl technique as described by Schuman, et al (14). The remaining elements were analyzed by emission spectroscopy according to the method of Chaplin and Dixon (6). The data were analyzed as a randomized block design and the Duncan's mean separations were computed from the analysis of variance.

RESULTS AND DISCUSSION

The physical parameters that were measured during onion maturation and the correlation coefficients over time are shown in Table 1. The slow decline of foliage moisture is of some interest when compared to the more rapid decline in neck tissue. Whether the moisture is retained through stomatal closure or through xylar import from the bulb and neck is not fully known. It appears that the use of several of the indices might provide a commercial onion grower with more precise information on the correct time to perform certain harvest operations such as the application of the dormancy promoter MH-30.

The mineral nutrition data are presented in Tables 3-8. The following is a brief synopsis of the results for each element from those tables:

Nitrogen: Total nitrogen in both leaf and neck tissue declined significantly during the final sampling periods. Concentration in the neck was substantially higher than the leaf. Directional changes in concentration were generally the same in both tissues at a given date (Fig. 1). Neck moisture had the best correlation with neck N, and leaf moisture the best with leaf N.

Potassium: Potassium accumulated in the neck while the concentration declined in the foliage. Neck moisture was the most reliable indicator of K concentration in both tissues.

Phosphorus: Phosphorus diminished in both tissues. Neck moisture gave the best correlation with leaf P and neck size the best with neck P.

Calcium: Calcium accumulated in both tissues. Several of the neck related indices proved equally effective in predicting calcium concentrations.

Magnesium: Magnesium accumulates slightly in the neck but is more or less unchanged in the leaf tissue. Neck moisture was the best predictor of neck Mg. No physical measure correlated well with leaf Mg.

Manganese: Manganese showed no pattern of accumulation or export in either tissue. No index correlated consistently with Mn concentration.

Iron: Iron accumulated strongly in both tissues. Neck size correlated best with neck Fe while top-fall rating was the best indicator of leaf Fe.

Copper: Copper showed a slight tendency to accumulate in both tissues. No physical measure gave a good correlation with concentration.

Zinc: Zinc declined strongly in both tissues. Neck measures were the best indicators for both leaf and neck Zn.

Boron: Strong accumulation in both neck and foliage. Neck measures generally the best indicators.

Aluminum: Aluminum showed a strong pattern of accumulation in both tissues. It is interesting to note that changes in iron and aluminum concentrations had mutual correlations of $r=0.959$ in the foliage and $r=0.971$ in the neck. Several neck indices proved the best indicators of Al concentration.

The onion begins to suppress leaf emergence once bulbing is initiated, leaving the bulb as the major remaining sink (1). Root emergence and growth also slows (1), a condition which is accelerated by the commercial practice of ceasing irrigation about forty days before harvest. Onion maturity is characterized by foliar dieback from the tips and the collapse of the foliar from a point in the neck or pseudostem. Phloem translocation from senescing leaves is not eliminated by top-fall (3) nor is the xylar transpiration stream suppressed (9). A very high proportion of the total yield is diverted into the bulb if the plant is left to mature normally (5). Zink (16) has found that 28% of the fresh weight and 36% of the dry weight was added to the bulb after top-fall. Lorenz and Hoyle (9) have found similar results. For most annual horticultural crops, the products of photosynthesis accumulate faster than minerals can be absorbed, which leads to a general decline in ion concentration on a dry weight basis in most tissues throughout ontogeny of the plant (10). However, certain minerals are often redistributed from leaves in response to changes in relative sink strengths within the plant. Mineral export from the leaves is dependent upon entry into and transport within the phloem. Generally, the pattern of redistribution of mineral elements resembles that of the pattern of photosynthetic export from leaves (10). In potatoes, the haulm is a source of N, P, and K for the growing daughter tubers at a time of decreasing rates of soil mineral uptake (11). Bennett (4), Nagai (12), and Wilson (15) have all found a decrease in total nitrogen in leaves and a corresponding increase in the bulb during maturation. Our results relative to shoot and stem N agree with those earlier results. Phosphorus mobility usually parallels that of nitrogen. This also agrees with our experimental results. In our study, K diminished in the leaves but accumulated in the neck. Whether this is in some way related to Wilson's (15) finding that the neck functions as a temporary storage site for translocated sugars during senescence is not clear. Magnesium, which is generally considered very phloem mobile, showed a tendency to accumulate in the neck with little concentration change in the leaves. This may indicate a lack of selective demand for magnesium by the bulb at this time. Zinc is depleted from the leaves and necks and must be regarded as mobile in this case. Loneragan, et al (8) have pointed out that under conditions of luxury consumption, zinc can be rapidly mobilized to the meristem. However, when senescing, a zinc deficient leaf will not release the ion into the redistribution pathway. The same pattern will also hold true for copper. In our experiments, copper tended to accumulate slightly. This corresponds well with the fact that the Lake Labish muck soils tend to be Cu deficient. Some of the Cu leaf analysis values we obtained (<8ppm) may indicate a marginal deficiency, especially prior to the start of active leaf senescence. The manganese data show a cyclic pattern of increase followed by decline. The results are probably due to the residue of fungicidal applications to control downey mildew although this could not be positively determined.

In the poorly phloem mobile category, both calcium and boron accumulate strongly as would have been expected. To what extent the accumulation represents a continued active fixation of the elements from the xylar stream as opposed to an apparent increase based on the loss of photosynthetic reserve from the leaves is not clear. The data for aluminum and iron are significantly clearer. The magnitude of the increase strongly suggests that both elements are being moved in the transpiration stream and are thus accumulating in the leaf. It is not known whether the increase in these ions is due to a breakdown in root ion selectivity which may occur as the roots senesce or due to a release of accumulated Al and Fe from the bulb and root. It is known that some plants will trap aluminum in the roots as a protective mechanism (7). However, the pattern of mutual increase of both iron and aluminum tends to suggest a breakdown in the root exclusion process during senescence. Further study will be needed to determine whether the increase in aluminum which we found is common to other onion cultivars grown on different soils and whether it may play an active role in senescence due to an induced late-season Al toxicity in the foliage.

Numerous other questions remain. In particular, it would be valuable to know with more precision the destination and role within the bulb of the minerals translocated from the foliage. The action of both the natural dormancy promoters and the applied dormancy promoter MH-30 in altering the pattern and timing of mineral distribution also needs to be examined. Answers to these and other late season mineral nutrition problems may enable us to better manipulate the commercial onion crop to increase yield and improve storage quality.

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Table 1. Physical changes in the onion during maturation

	Neck Moisture%	Foliar Moisture%	Neck Size (mm)	Bulb Size (mm)	Neck/bulb ratio	Top-fall rating[y]
19 Aug	91.6	93.0	16.4	56.6	.306	1.00
23 Aug	90.6	91.9	17.4	59.0	.308	1.44
27 Aug	90.3	90.3	18.4	64.0	.291	1.60
31 Aug	90.4	91.4	17.8	69.4	.257	2.08
3 Sept	89.7	90.4	16.4	68.9	.238	2.20
7 Sept	89.8	91.3	15.4	73.9	.209	2.52
9 Sept	89.2	91.2	13.7	72.7	.188	2.60
11 Sept	88.2	91.6	11.5	71.1	.162	2.70
15 Sept	85.5	91.5	9.5	72.2	.131	3.00
20 Sept	78.4	87.0	8.5	72.6	.115	3.00
23 Sept	75.9	76.1	5.4	72.3	.077	3.00
Correlation cofficient for date[x]	-.851**[x]	-.643*	-.922**	.834**	-.990**	.967**

x * sig. at P < .05, ** sig. at P < .01.

y Top-fall rated 1 = firm, 2 = medium, and 3 = soft.

Table 2. Mean concentration of N, K. P, and Ca in onion neck and leaf tissue at various sample dates.

	%N[x]		%K		%P		%Ca	
	neck	leaf	neck	leaf	neck	leaf	neck	leaf
19 Aug	1.96	.97	2.48	1.76	0.32	0.18	1.03	1.27
23 Aug	2.08bc	.79	2.19c	1.84	0.51a	0.18	1.29cd	1.08
27 Aug	2.61a	.83cd	2.14c	1.65ab	0.46ab	0.20ab	1.10d	1.07c
31 Aug	2.16abc	.89bc	2.34c	1.92a	0.33bc	0.21ab	1.56bc	1.22bc
3 Sept	2.60a	.95ab	2.48abc	1.90a	0.32bc	0.24a	1.58bc	1.31bc
7 Sept	2.09bc	.84cd	2.11c	1.88a	0.44ab	0.17bc	1.61bc	1.16bc
9 Sept	2.23ab	1.03a	2.12c	1.69ab	0.31bc	0.17bc	1.60bc	1.35b
11 Sept	1.92bc	.97ab	2.29bc	1.72ab	0.35bc	0.12cd	2.22a	1.68a
15 Sept	1.72c	.87bc	2.41abc	1.40bc	0.24cd	0.11d	1.77b	1.67a
20 Sept	1.21d	.75de	2.94ab	1.09cd	0.11de	0.08d	2.23a	1.77a
23 Sept	1.08d	.65e	2.92a	.95d	0.06e	0.08d	2.54a	1.84a
$s_{\bar{x}}$	0.138	0.035	0.211	0.113	0.044	0.017	0.117	0.082
n	2	4	2	4	2	4	2	4

x N, K, P, and Ca are reported in percentage of tissue dry weight.
Mean separation within columns by Duncan's multiple range test, 5%. Values lacking separation letters were not included in statistical analysis due to single sample.

Table 3. Mean concentration of Mg, Mn, Fe, and Cu in onion neck and leaf tissue at various sample dates.

	%Mg[x]		Mn, ppm		Fe, ppm		Cu, ppm	
	neck	leaf	neck	leaf	neck	leaf	neck	leaf
19 Aug	0.16	0.14	52	67	134	92	0	2
23 Aug	0.24bc	0.10	75ab	43	122c	116	5cde	2
27 Aug	0.14c	0.08c	30c	29d	78c	147c	1e	4b
31 Aug	0.25bc	0.15ab	65bc	76abc	104c	246c	7bcd	13a
3 Sept	0.23bc	0.15ab	54bc	62bcd	117c	215c	4de	13a
7 Sept	0.17c	0.10bc	37bc	47cd	186bc	307bc	5cde	9ab
9 Sept	0.26c	0.14ab	30c	97a	177bc	547a	9bc	10ab
11 Sept	0.33b	0.13abc	58bc	91ab	302bc	691a	10ab	11ab
15 Sept	0.29bc	0.15ab	53bc	61bcd	833a	514ab	15a	5b
20 Sept	0.54a	0.15ab	52bc	62bcd	459b	557a	10ab	10ab
23 Sept	0.48a	0.16a	109	75abc	842a	529ab	3de	9ab
$s\bar{x}$	0.044	0.016	12.5	10.5	91.1	73.8	1.41	2.12
n	2	4	2	4	2	4	2	4

x Mg reported in percentage, Mn, Fe, and Cu reported in ppm of tissue dry weight

Mean separation within columns by Duncan's multiple range test, 5%. Values lacking separation letters were not included in statistical analysis due to single sample.

Table 4. Mean concentration of B, Zn, and Al in onion neck and leaf tissue at various sample dates.

	B^x,ppm		Zn,ppm		Al,ppm	
	neck	leaf	neck	leaf	neck	leaf
19 Aug	14	19	19	18	19	85
23 Aug	34	19	26a	7	33c	97
27 Aug	22b	17b	11bc	13ab	16c	172d
31 Aug	21b	22b	17abc	17a	20c	260d
3 Sept	21b	23b	22ab	20a	91c	215d
7 Sept	23ab	20b	22ab	18a	150c	406cd
9 Sept	20b	22b	14abc	19a	129c	526bc
11 Sept	24ab	31a	12abc	12ab	374bc	826a
15 Sept	20b	30a	12abc	6b	1076a	650abc
20 Sept	29ab	34a	4c	5b	540b	642abc
23 Sept	32a	32a	5c	5b	1291a	712ab
$s_{\bar{x}}$	2.63	2.05	3.89	2.87	111.6	83.6
n	2	4	2	4	2	4

x B, Zn, and Al are reported in ppm of tissue dry weight.
Mean separation within columns by Duncan's multiple range test, 5%. Values lacking separation letters were not included in statistical analysis due to single sample.

Table 5. Correlation coefficients of onion leaf mineral composition versus several growth variables

	Date	Neck Moisture	Leaf Moisture	Neck Size	Bulb Size	Neck/Bulb Ratio	Topfall Rating
Nitrogen	-.364*[y]	.648**	.667**	.431**	-.022	.344*	-.195
Potassium	-.682**	.819**	.680**	.755**	-.275	.687**	-.532**
Phosphorus	-.727**	.720**	.481**	.798**	-.399**	.753**	-.650**
Calcium	.801**	-.747**	-.521**	-.851**	.474**	-.831**	.739**
Magnesium	.364*	-.317*	-.231	-.361*	.281	-.382*	.365*
Manganese	.299	-.116	-.078	-.279	.338*	-.328*	.347*
Iron	.705**	-.473**	-.245	-.674**	.601**	-.723**	.732**
Copper	.218	-.072	-.074	-.053	.422**	-.179	.276
Boron	.755**	-.695**	-.440**	-.780**	.474**	-.775**	.714**
Zinc	-.452**	.597**	.420**	.570**	.052	.472**	-.347*
Aluminum	.766**	.555**	-.343*	-.749**	.620**	-.788**	.775**

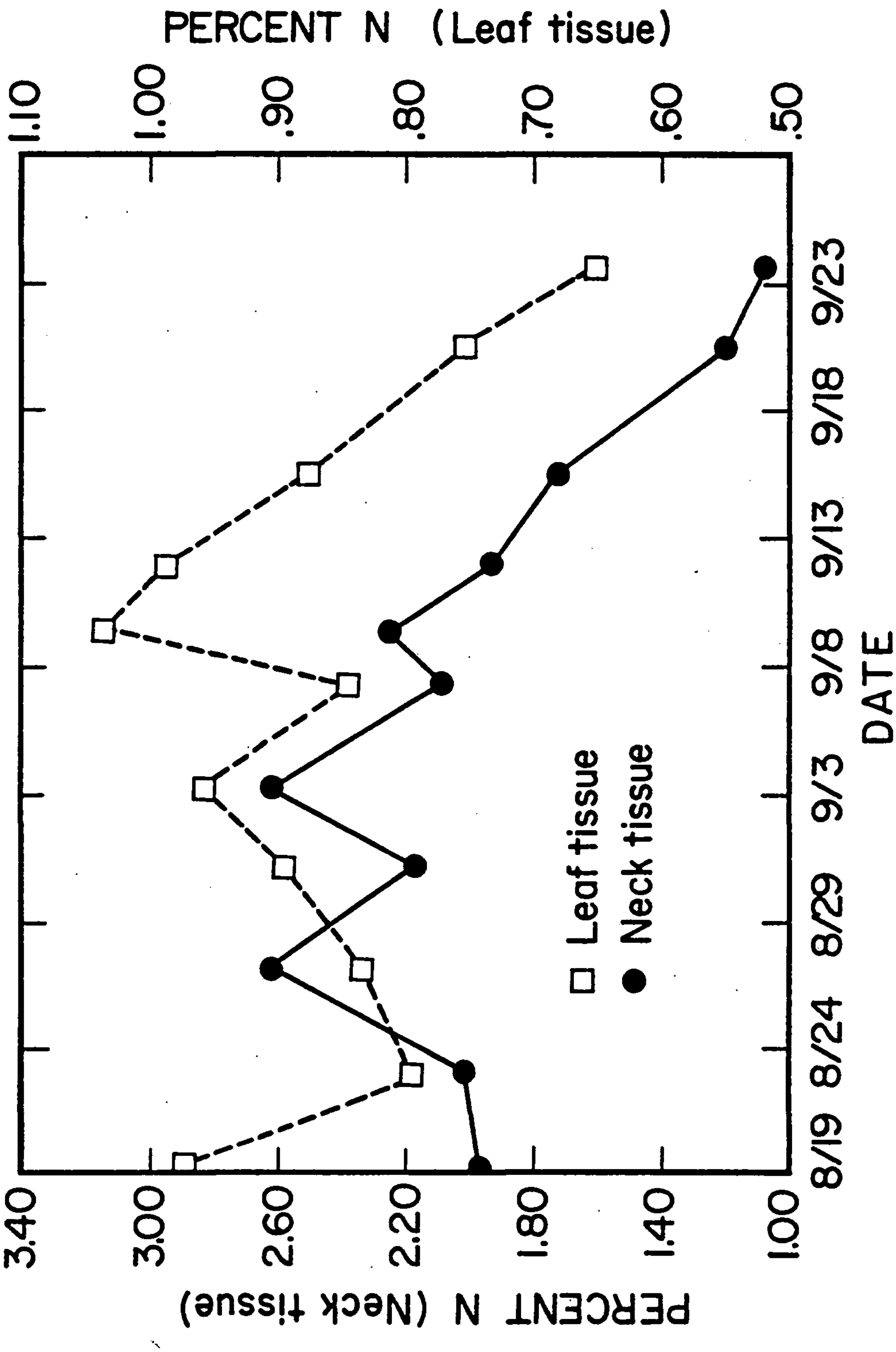
y * Significant at p < .05; ** Significant at p < 01; N = 39 for all catagories.

Table 6. Correlation coefficients of onion neck mineral composition versus several growth variables

	Date	Neck Moisture	Leaf Moisture	Neck Size	Bulb Size	Neck/Bulb Ratio	Topfall Rating
Nitrogen	-.723**	.861**	.660**	.857**	-.348	.763**	-.602**
Potassium	.560**	-.772**	-.692**	-.651**	.218	-.575**	.412
Phosphorus	-.785**	.846**	.697**	.823**	-.501*	.804**	-.675**
Calcium	.884**	-.813**	-.674**	-.865**	.662**	-.890**	.862**
Magnesium	.769**	-.868**	-.646**	-.811**	.433	-.770**	.662
Manganese	.270	-.504*	-.634**	-.434*	-.050	-.312	.151
Iron	.759**	-.764**	-.610**	-.863**	.442*	-.805**	.690**
Copper	.517*	-.211	.171	-.445*	.539*	-.529*	.646**
Boron	.703**	-.772**	-.743**	-.646**	.503*	-.659**	.586**
Zinc	-.644**	.687**	.534*	.654**	-.400	.645**	-.539*
Aluminum	.786**	-.801**	-.690**	-.886**	-.460*	-.830**	.704**

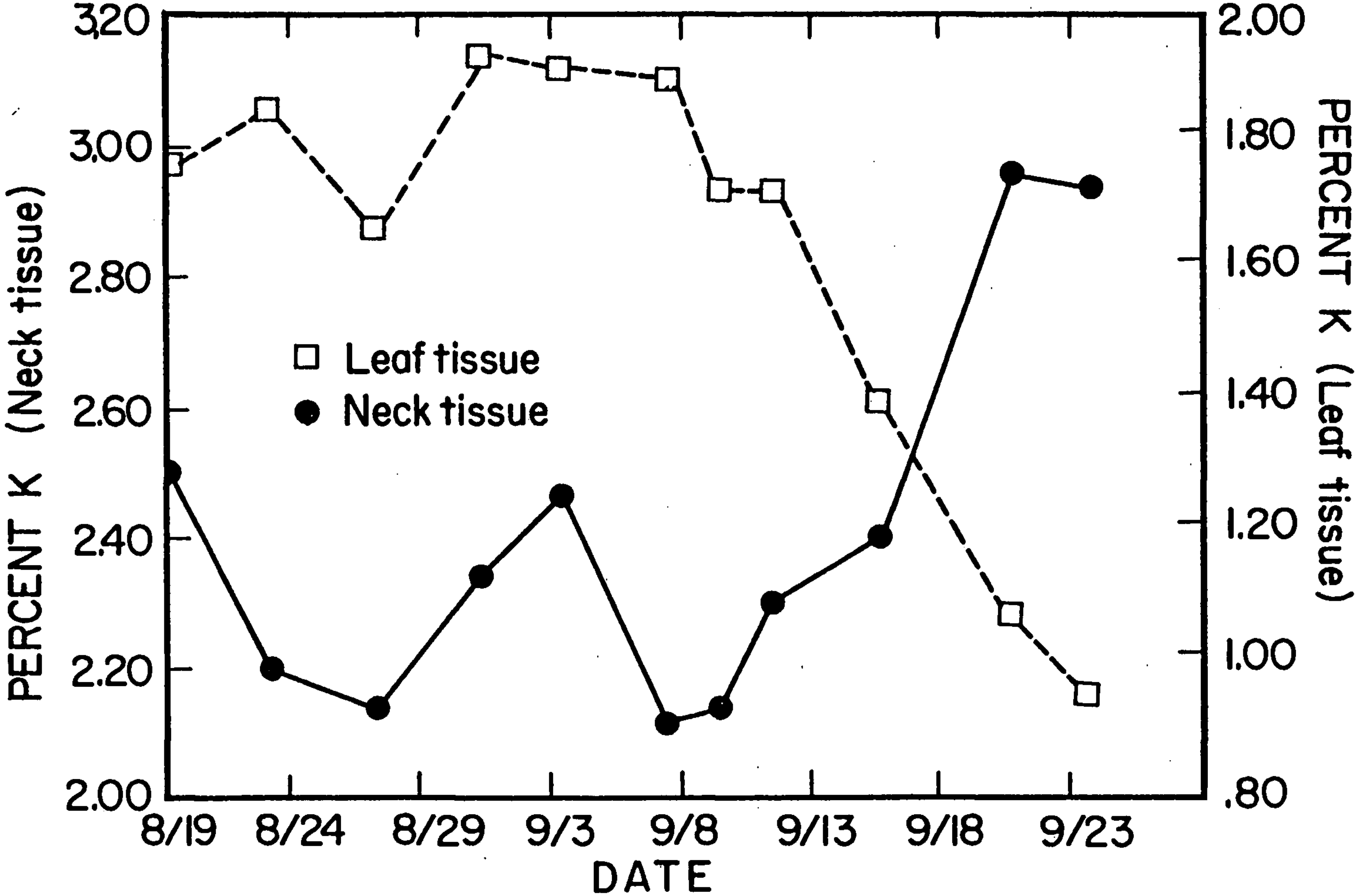
y * Significant at $p < .05$; ** Significant at $p < .01$; N = 21 for all catagories except Boron where N = 20.

Figure 1: N concentration (% dry weight) in onion leaf and neck tissue as a function of time during bulb maturation.



PERCENT N (Leaf tissue)
1.10
1.00
.90
.80
.70
.60
.50
PERCENT N (Neck tissue)
3.40
3.00
2.60
2.20
1.80
1.40
1.00
DATE
8/19
8/24
8/29
9/3
9/8
9/13
9/18
9/23
Leaf tissue
Neck tissue

Figure 2: K concentration (% dry weight) in onion leaf and neck tissue as a function of time.



3.20
3.00
2.80
2.60
2.40
2.20
2.00
PERCENT K (Neck tissue)
2.00
1.80
1.60
1.40
1.20
1.00
.80
PERCENT K (Leaf tissue)
Leaf tissue
Neck tissue
8/19
8/24
8/29
9/3
9/8
9/13
9/18
9/23
DATE

Figure 3. P concentration (% dry weight) in onion leaf and neck tissue as a function of time.

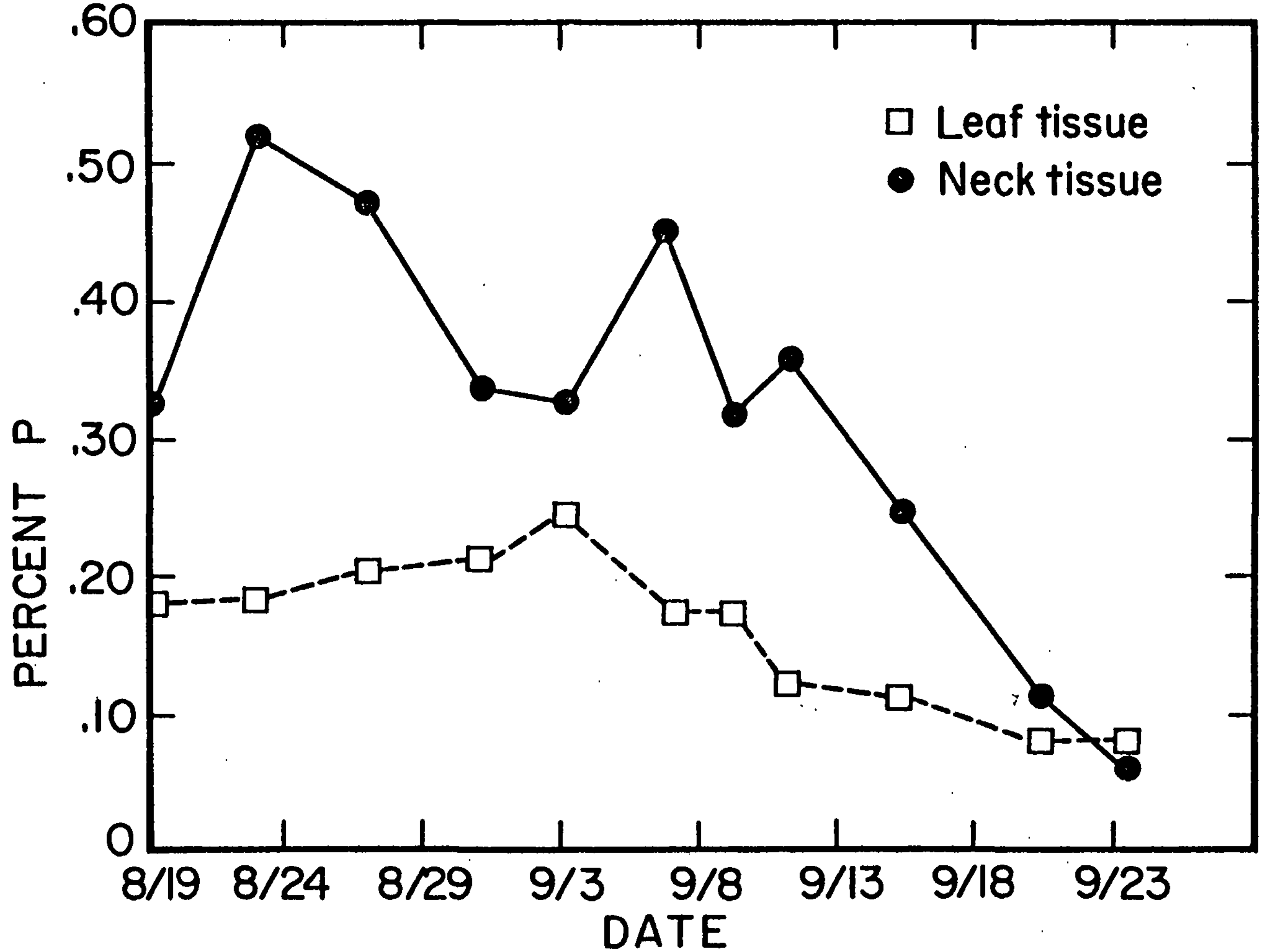

Leaf tissue
Neck tissue
PERCENT P
.60
.50
.40
.30
.20
.10
0
8/19
8/24
8/29
9/3
9/8
9/13
9/18
9/23
DATE

Figure 4: Ca concentration (% dry weight) in onion neck and leaf tissue as a function of time.

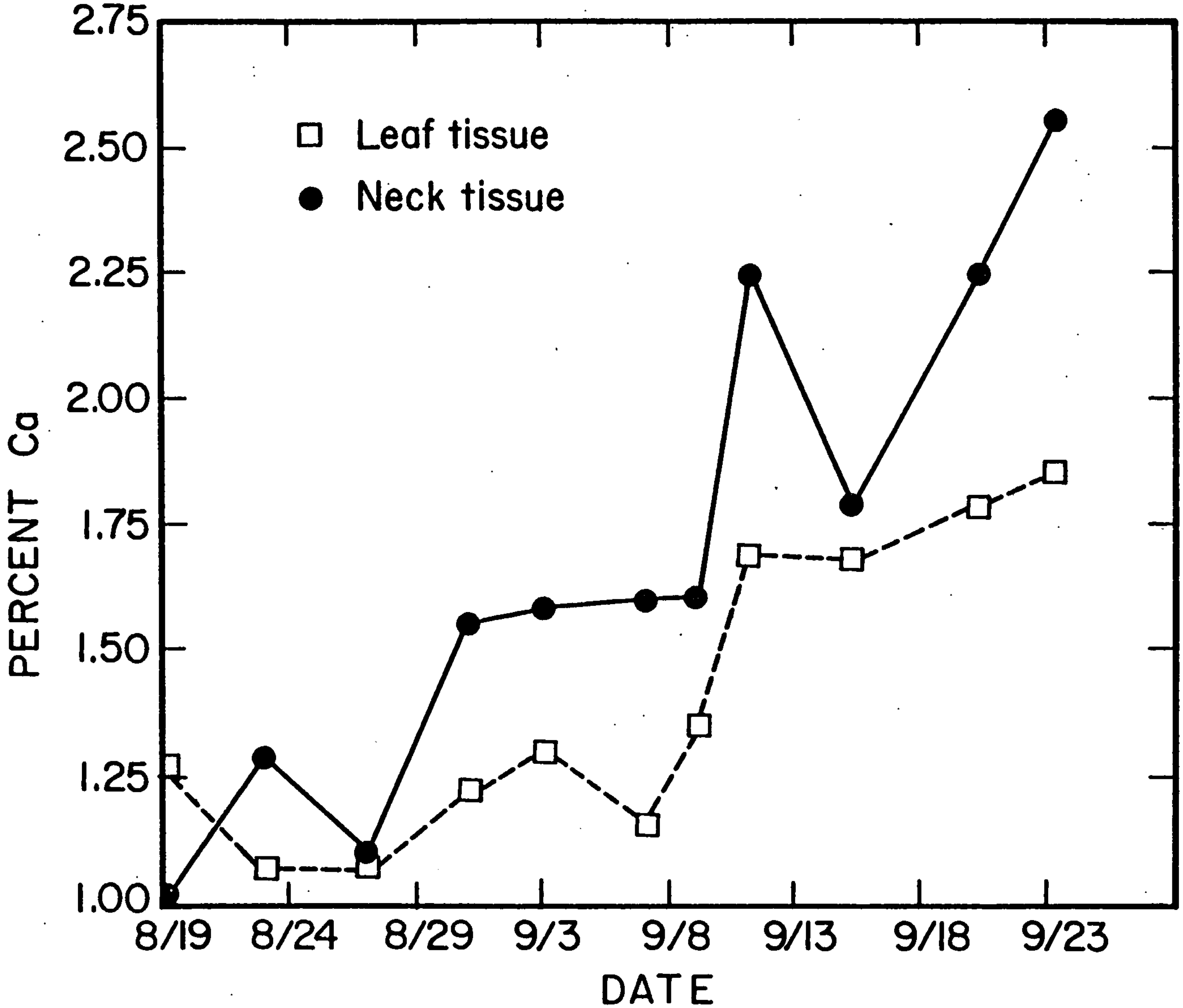
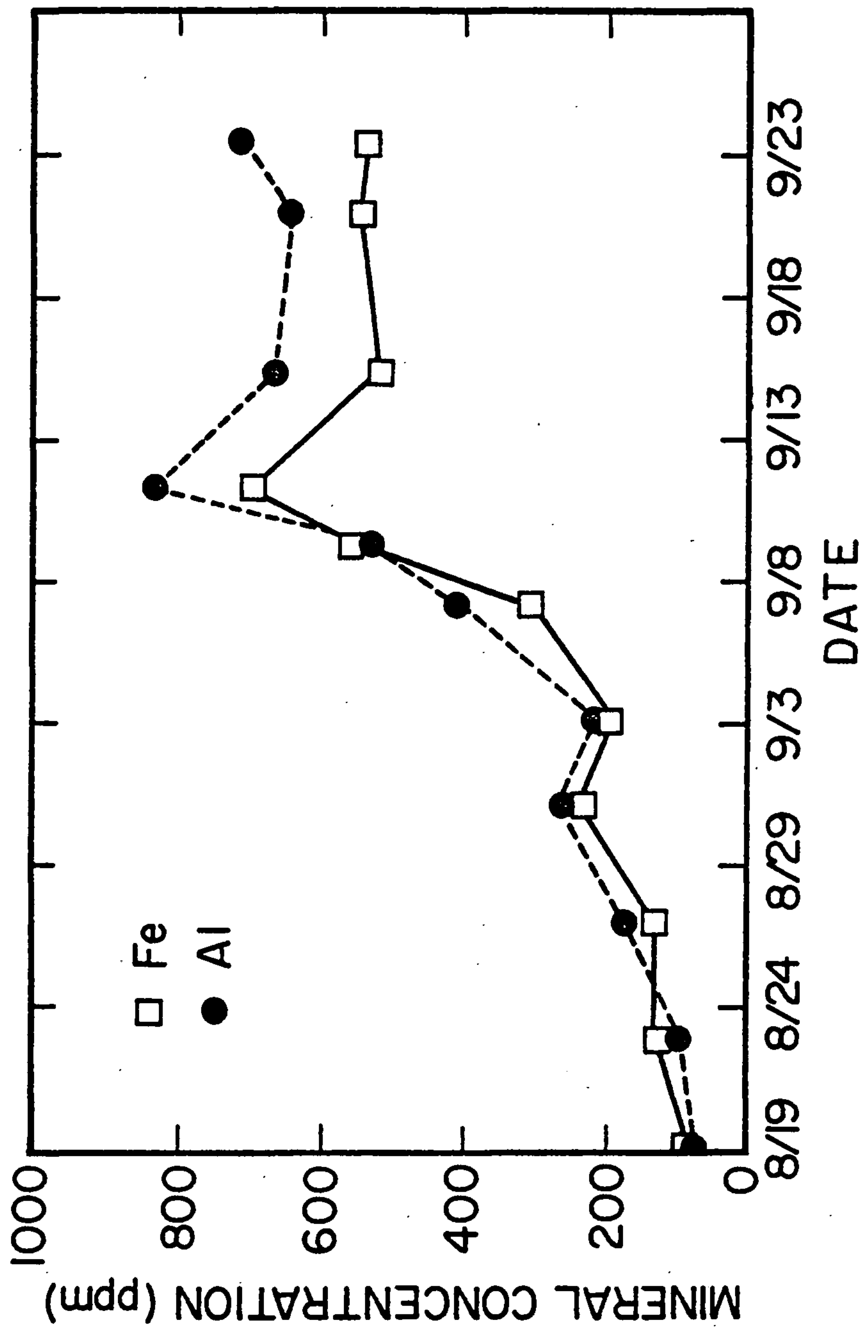

Leaf tissue
Neck tissue
PERCENT Ca
2.75
2.50
2.25
2.00
1.75
1.50
1.25
1.00
8/19
8/24
8/29
9/3
9/8
9/13
9/18
9/23
DATE

Figure 5: Fe and Al concentration (ppm of dry weight) in onion leaf tissue as a function of time.


Fe
Al
MINERAL CONCENTRATION (ppm)
0
200
400
600
800
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APPENDIX

Table 1. Statistical information relevant to the paper entitled 'Foliar chemical desiccation and onion storage quality'.

1. Storage disease x storage sprouting (1975). r = .108, n = 60.
2. " " " " " (1976). r = .005, n = 48.
3. Final neck moisture x storage disease (1975). r = .471, n = 15.
4. " " " " " " (1976). r = .167, n = 16.
5. " " " " " sprout (1975). r = .191, n = 15.
6. " " " " " " (1976). r = .113, n = 16.
7. Paired storage disease - early vs late treatments (1975). calc. t = 2.44, n = 23.
8. Paired storage disease - early vs late treatments (1976). calc. t = 2.35, n = 20.
9. Paired storage sprouts - early vs late treatments (1975). calc. t = 1.63, n= 23.
10. Paired storage sprouts - early vs late treatments (1976). calc. t = .876, n = 20.
11. Treatment neck phenol (end) x storage disease (1976). r = .847, n = 5.
12. " " " " " " sprout (1976). r = .037, n = 5.
13. Treatment neck phenol (sample date 1) x storage disease. r = -.121, n = 5.
14. Treatment neck phenol (sample date 2) x storage disease. r = .789, n = 5.
15. Treatment neck phenol (sample date 3) x storage disease. r = .773, n = 5.
16. Treatment neck phenol (sample date 4) x storage disease. r = .636, n = 5.
17. Treatment neck phenol (sample date 5) x storage disease. r = .942, n = 5.

18. Bulb size (<50mm) x treatments. F = .220.

19. " " (51-63mm) x treatments. F = .297.

20. " " (64-76mm) " " . F = .354.

21. " " (77-89mm) " " . F = 1.310.

22. " " (>90mm) " " . F. = .667.

EVALUATION OF TOP DESICCANTS ON CURING OF DANVERS YELLOW GLOBE ONIONS AND SUBSEQUENT STORAGE QUALITY

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Abstract

Foliar sprays of Ethephon, Endothall, Paraquat, Stoddard Solvent, and Uniroyal N-252 were each applied at two concentrations, and at two dates 12 and 5 days before lifting to hasten field curing and desiccation of the leaves. Bulbs were then allowed to cure in the field for 8 days prior to storage at 40°F and 80% R.H. Progressive moisture loss in the neck region was monitored as well as sprouting and rots in storage.

Significant differences in bulb-neck moisture contents were found, with Ethephon, Endothall, and Paraquat producing the driest necks. In general, the earlier sprays were more desiccating than the later sprays. However, neck moisture content produced by any of the sprays could not be correlated with storage losses. The low rates of Endothall, and Stoddard Solvent produced the least loss due to storage rots and Paraquat the greatest.

Introduction

Onions must be properly cured to be stored satisfactorily for any period of time. This curing process generally involves a gradual reduction in the moisture content of the outer scales and foliage, especially in the neck region. Curing is usually accomplished by lifting onions from the soil when one-half of the tops have fallen. The onions are placed on the soil in windrows and allowed to sun dry. These windrows are periodically turned during the 10 to 14 day curing period. In Western Oregon, onions are stored with their tops intact. Other onion growing areas will top their onions at the time they are moved into storage.

Failure to adequately dry onions renders them susceptible to storage diseases, especially neck rot (Botrytis alii Munn.). In Western Oregon, the curing period is often interrupted by one to several days of rain. In most years, good curing weather returns and the onions can be field dried acceptably, though it is almost inevitable that there will be some marginal increase in storage rot losses. However, it sometimes happens that the onions go into storage in a wet condition. In such cases, the percentage of storage rots rises dramatically (6).

Several investigators have attempted to reduce the time in curing by foliar application of desiccating compounds. Zschau and Böttcher (7) in East Germany found that both Diquat and Paraquat, when applied at top fall, gave satisfactory desiccation of leaves. However, both compounds substantially increased storage rot losses in comparison to the control. Isenberg (2,3) and Pendergrass, et al. (5) have studied the use of a mixture of di-α branched decanoic acids, called Neo-Decanoic Acid (NDA) for artificial foliar curing. This compound was orginally formulated as a harvest aid for cotton and is currently being registered for onion curing under the trade name of Topper 5-E by Agway, Inc. The investigators applied NDA at 50% top fall and were able to reduce foliage moisture in the neck region to 42% in comparison to controls at 80-90%. This produced a moisture content acceptable for machine harvesting, one of the experimental objectives. Treatment with NDA neither significantly increased or decreased storage losses, despite the dramatic reduction in moisture content. Several other articles (1,4) dealt with NDA residue recovery.

Materials and methods

The experiments were conducted in 1974 and 1975 in Marion County, Oregon with Danvers Yellow Globe onions from commercial fields on the Semiahmoo muck soil of Lake Labish. Unless otherwise specified, normal commercial practices were followed. A split-block design with four replications was used. Blocks were 3.8 m long by 1.0 m (4 rows) wide. The various experimental sprays were applied with a double bicycle wheel plot sprayer utilizing compressed air. Two and one-half ml of the surfactant X-77 (Alkaryl Polyoxethylene Glycol with free fatty acids and Isopropanol mfg. by Kalo Laboratories, Kansas City, MO 64137) were added to each of the spray treatments with the exception of the Stoddard Solvent. Several potential top desiccant chemicals were selected and concentrations prepared as follows: Uniroyal N-252 (2,3-dihydro-5,6-dimethyl-1,4-dithiin 1,1,4,4-tetraoxide from Uniroyal Chemical, Amity Rd., Bethany, CT) at 1 lb/acre and 4 lb/acre, Endothall (7-oxabicyclo (2.2.1) heptane-2,3-dicarboxylic acid as the mono (N,N-dimethylalkylamine) salt from Agchem-Decco Division-Pennwalt Corp., Monrovia, CA) at 1 lb/acre and 4 lb/acre, Paraquat (1,1'-dimethyl-4,4'-dipyridilium dimethylsulfate) at ½ lb/acre and 1 lb/acre; Stoddard Solvent petroleum fraction at 50 gal/acre and 100 gal/acre, Ethephon (2-Chloroethylphosphonic acid syn. "Ethrel" from Amchem Products, Ambler, PA) at 1 lb/acre and 4 lb/acre. First spraying was done 5 days after the normal commercial application of MH-30 when 50% of the tops had fallen. In 1974, the onions were sprayed 7 days before lifting. In 1975, the onions were sprayed 12 and 5 days before lifting. During the second year, samples for neck moisture were taken from the various treatments using a 2.5 cm section of onion neck directly above the shoulder. These samples were then weighed and dried in a vacuum oven at 65°C to determine moisture content. The onions were removed from the field at the same time as the commercial crop 9 days after lifting. The onions were placed in storage in burlap bags at 5°C and approximately 80-85% R.H. Five months after going into storage, the onions were evaluated for incidence of rot and root and shoot sprouting. No effort was made to evaluate the extent of either factor on a given onion.

Results

All of the desiccants were effective in drying onion tops, but there were substantial differences in the rates of drying, residual moistures in the neck tissues, and incidences of rot after 5 months of storage. Paraquat was very fast acting in drying the tops and reduced the number of three inch and larger sized onions (table 1) to 5% compared with 27% in the control. The other compounds also reduced size, but not as extensively as Paraquat. Ethephon had less of an effect on size reduction than the other compounds. There was relatively little difference in weight loss during storage, except for the Paraquat treatment (table 2) which was slightly greater. The most significant storage quality effect was on the incidence of storage rots, mainly Botrytis spp. neck rot (tables 2,3). Paraquat had consistently higher percentages of rot than the other treatments, followed closely by the 4 lb/acre early Endothall. Ironically, the 1 lb/acre rate of Endothall in both early and late application had a much lower rot incidence and was comparable to the control. Stoddard Solvent only slightly increased storage rots as did Ethephon. In all cases, the higher concentrations of top desiccants produced more susceptibility to rots than lower concentrations. Root sprouting in the 1974 trial was also promoted by most of the treatments except Paraquat and the 1 lb/acre rate of Ethephon.

Moisture loss in the neck tissues was most dramatically affected by the early Ethephon treatments, despite somewhat slower activity in drying the tops (table 3, fig. 1). Paraquat was also effective in promoting moisture loss in the neck tissues. Both rates of Endothall and the low rate of Stoddard Solvent in the early sprays reduced neck moistures to 70-75% (fig. 2,3). Unexpectedly, the late applications of Stoddard Solvent actually resulted in an increase in neck tissue moisture which eventually evened out in storage by mid-March (table 3).

Discussion

The timing of the 1974 desiccant sprays was at a physiologically earlier stage than the 1975 timing and probably explains why the effects on size reduction were significant for the faster desiccating sprays such as Paraquat. The weather conditions in 1974 were excellent for natural curing and undoubtedly were a dominant factor in the relatively low rot incidence of 1% in the controls. Typical losses due to rots have averaged 6-7% over the long term. The higher 1975 rot incidence (11%) demonstrates the effects of a single day of light rain which fell two days after lifting.

The effectiveness of these desiccants for drying of onion tops and the increased incidence of storage rots presents an enigma. Either the fast acting desiccants are preventing the translocation of endogenous dormancy promoters and antifungal agents to the bulb or there may be chemically induced necrosis rendering the bulbs more susceptible to pathogens or for other less obvious reasons. The actions of Ethephon and the lower rate of Endothall seem to more nearly approximate the natural senescent processes associated with curing. Unexpectedly, there was little, if any correlation between neck moisture content and rot incidence.

Effects of desiccants on sprouting suggest that the maleic hydrazide dormancy promoter sprayed prior to the desiccant was not translocating to the bulb at effective concentrations except for the slower acting desiccants. The increase in neck moisture content from Stoddard Solvent is puzzling, particularly since it did not seem to promote neck rot. More research is needed to find a desiccant which will dry the tops effectively, but allow the endogenous dormancy promoters and antifungal compounds to translocate to the bulb and reduce the currently unacceptable rot incidences.

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Table 1 - Onion top desiccant trials. (1974)

Treatments		Desiccation rating* after 6 days	Number in stand	Size distribution % of total: Less than 2"	2"-2.5"	2.5"-3"	More than 3"
Uniroyal N-252	1 lb/acre	4	289	9	36	44	10
	4 lb/acre	4	305	15	33	40	12
Endothall	1 lb/acre	4+	315	16	37	38	9
	4 lb/acre	5	283	18	30	41	11
Paraquat	1 lb/acre	5	310	13	37	45	5
Stoddard Solvent	113 gal/acre	4	292	15	25	46	13
Ethrel	1 lb/acre	3+	306	14	27	44	15
	4 lb/acre	3	310	16	22	44	17
Control	unsprayed	2	262	14	20	38	27

*Rated subjectively 1-5, 1 being least effective.

Table 2 - Top desiccant effects on storage quality of Danvers Yellow Globe onions held at 5°C and 80% relative humidity for 5 months. (1974)

Treatments		% weight loss	% rot	% root sprout	% shoot sprout
Uniroyal N-252	1 lb/acre	2.78	14	36	2.7
	4 lb/acre	1.74	0	39	1.8
Endothall	1 lb/acre	1.87	4	47	2.6
	4 lb/acre	2.46	29	61	1.0
Paraquat	1 lb/acre	3.35	47	2	0.0
Stoddard Solvent	113 gal/acre	1.60	8	27	2.0
Ethrel	1 lb/acre	3.17	2	5	5.2
	4 lb/acre	2.83	11	38	2.3
Control	unsprayed	1.81	1	10	0.0

Table 3 - Onion top desiccant effects on neck moisture content at various sampling dates. (1975-1976)

Treatments		29 Aug	4 Sept	8 Sept	13 Sept	18 Sept	15 Mar	15 Mar
		Percent moisture						% Rots
Control		92.30	86.50	84.70	86.03	86.07	67.98	11.00
Early treatments - 12 days before lifting								
Ethephon	2 lb/acre		87.02	86.40	71.53**	66.67**	67.07	15.00
Ethephon	4 lb/acre		88.44	79.60*	74.16**	56.10**	73.62	12.50
Paraquat	½ lb/acre		89.28	85.33	76.65**	68.77**	57.18	24.50**
Paraquat	1 lb/acre		92.18*	86.45	80.68	76.80*	63.60	24.50**
Endothall	1 lb/acre		89.36	85.08	71.62**	67.59**	53.46**	9.50
Endothall	4 lb/acre		88.48	86.00	80.97*	75.75*	73.75	25.00**
Stoddard Solvent	50 gal/acre		87.02	84.45	79.58*	67.98**	68.30	10.00
Stoddard Solvent	100 gal/acre		87.10	84.81	86.20	79.67	77.18	16.50
Late treatments - 5 days before lifting								
Paraquat	½ lb/acre			84.07	78.73*	76.55*	36.66**	12.50
Paraquat	1 lb/acre			85.50	84.03	73.57**	74.28	20.50*
Endothall	1 lb/acre			83.38	81.63	74.02**	67.70	7.50
Endothall	4 lb/acre			86.33	83.46	72.97**	75.43	15.00
Stoddard Solvent	50 gal/acre			82.62	86.07	87.42	62.93	11.00
Stoddard Solvent	100 gal/acre			85.33	86.03	89.28	70.58	16.50
LSD - 05*			2.94	4.67	5.71	8.42	11.16	8.84
LSD - 01**			3.97	6.19	7.58	11.17	14.82	10.88

Means of 8 samples per treatment

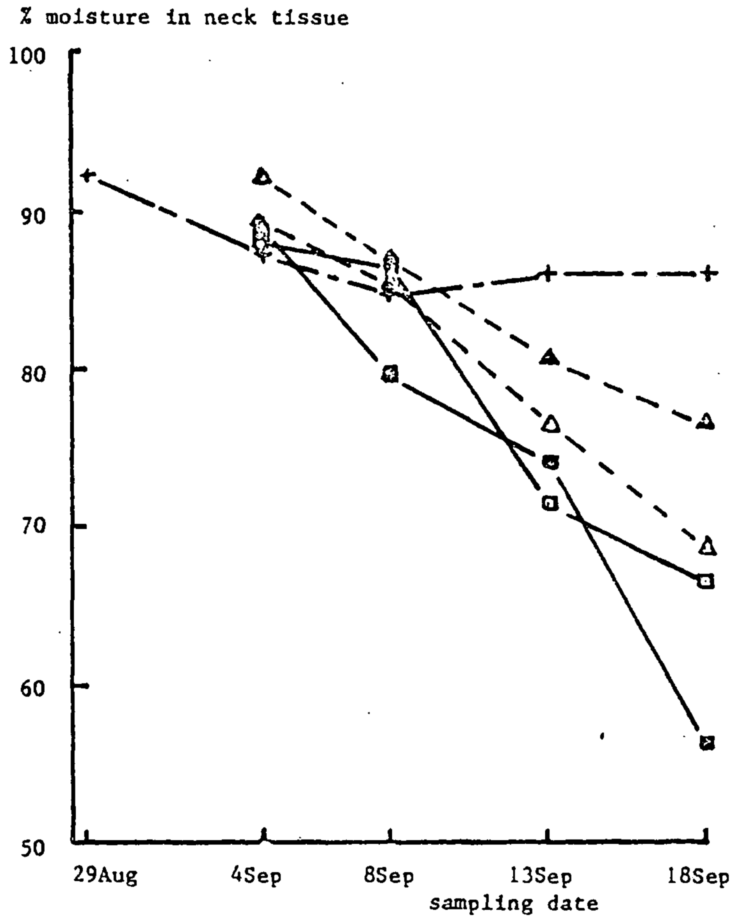

Figure 1 - Onion neck moisture after top desiccant sprays.
+ control
□ ethephon 1 lb/A applied 29 Aug
⊠ ethephon 4 lb/A "
△ paraquat ½ lb/A applied 29 Aug
▲ paraquat 1 lb/A "

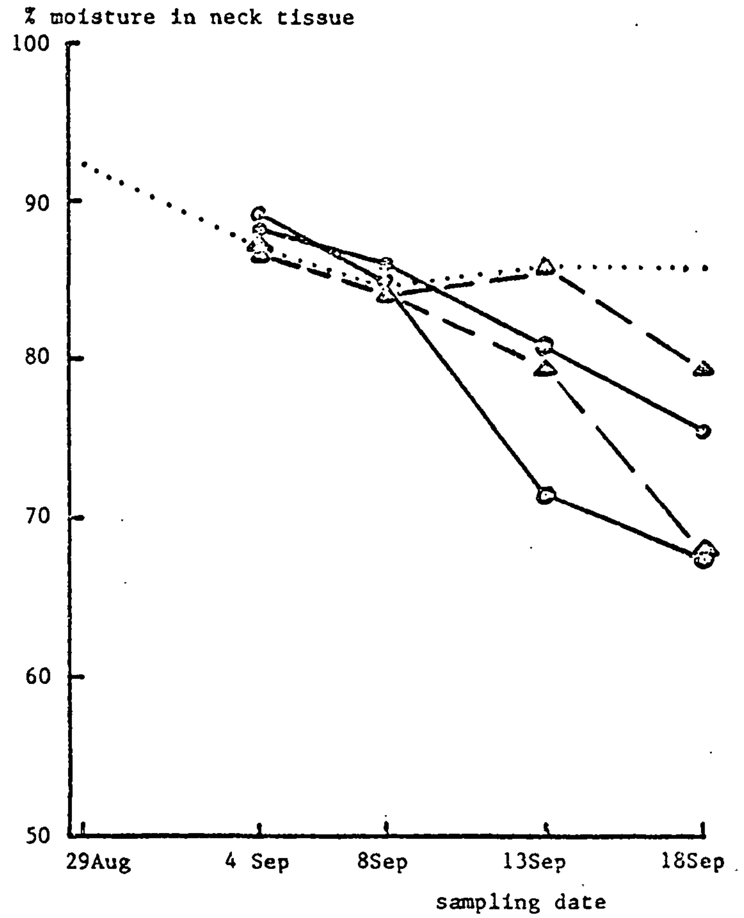

Figure 2 - Onion neck moisture after top dessicant sprays.

···· control
endothall 1 lb/A applied 29 Aug
endothall 4 lb/A "
stoddard solvent 50 gal/A "
stoddard solvent100 gal/A "

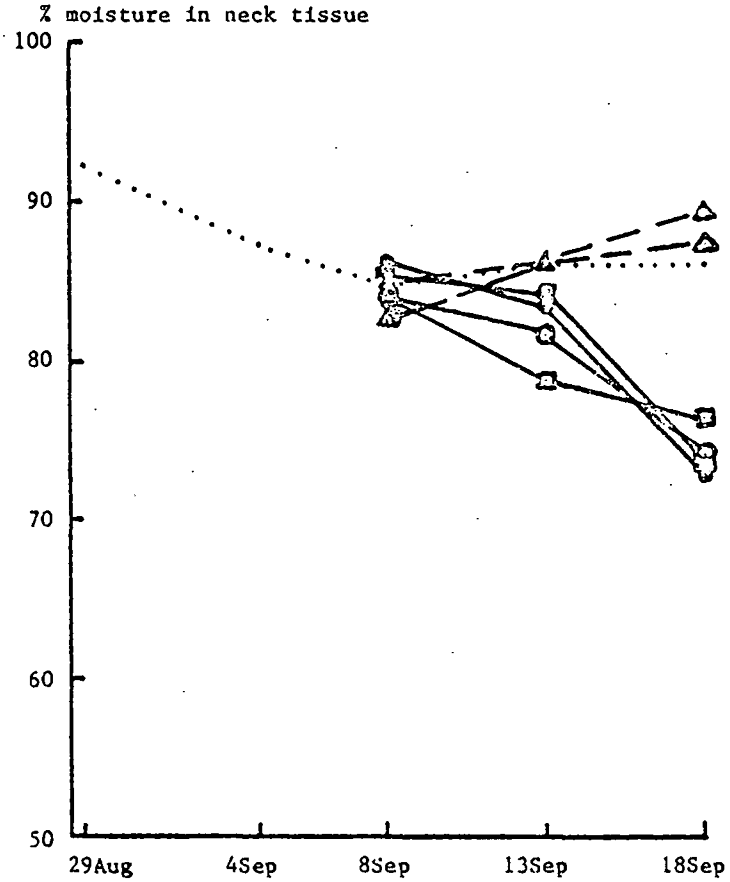

Figure 3 - Onion neck moisture after top desiccant sprays.

.... control
paraquat ½ lb/A applied 5 Sep
paraquat 1 lb/A "
endothall 1 lb/A "
endothall 4 lb/A "
stoddard solvent 50 gal/A "
stoddard solvent 100 gal/A "